THE PEMAQUID LAKES (MAINE)
1993
LAKES LAY MONITORING PROGRAM

by
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edited by
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NEW HAMPSHIRE LAKES LAY MONITORING PROGRAM

NH LLMP

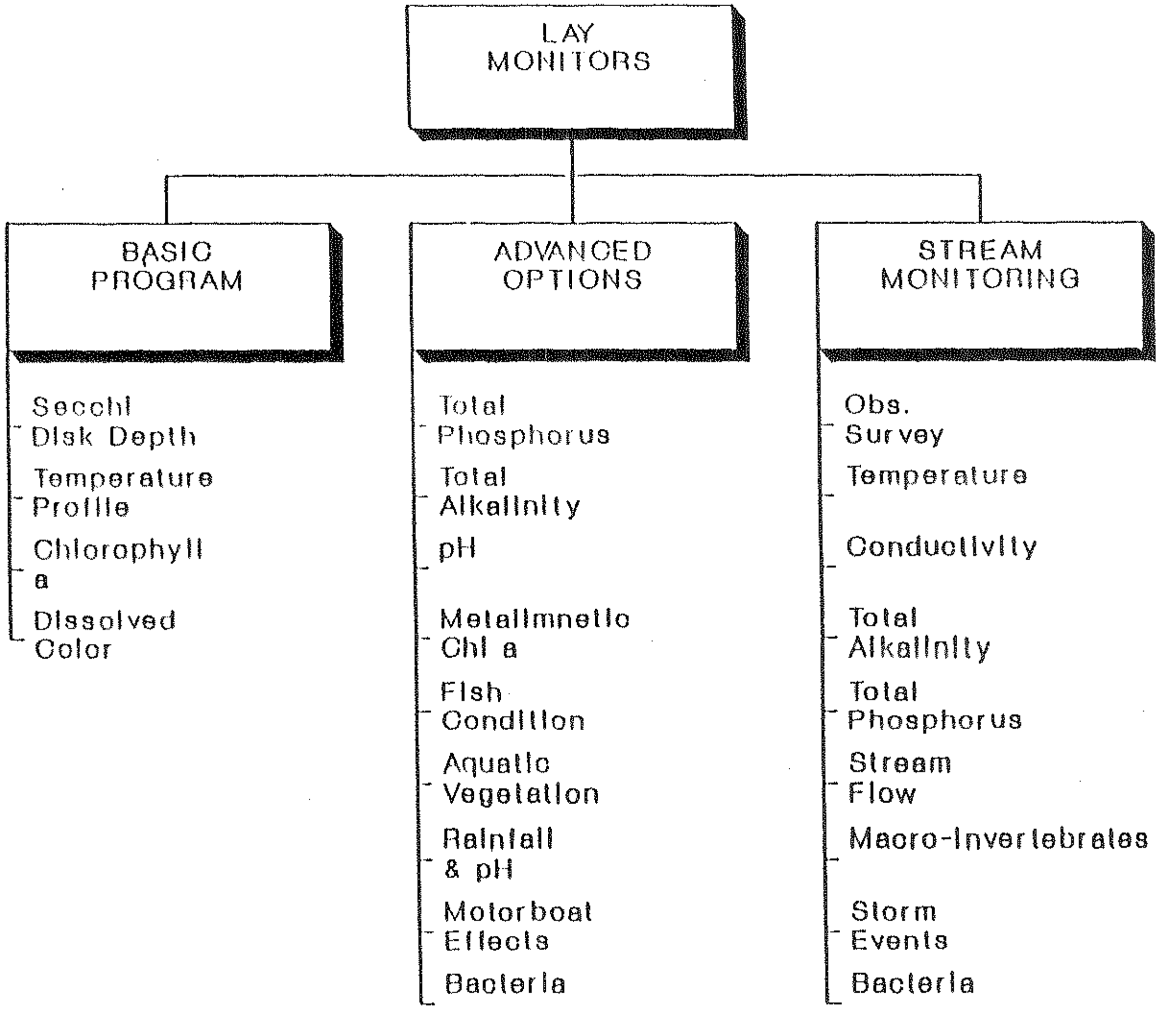
FRESHWATER BIOLOGY GROUP
University of New Hampshire
Durham

UNIVERSITY OF NEW HAMPSHIRE
COOPERATIVE EXTENSION
Helping You To Put Knowledge And Research To Work

To obtain more information about the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (J.Schloss) at (603) 862-3848
Dr. Baker at 862-3845 or Dr. Haney at 862-2106

PARAMETERS SAMPLED

NH LAKES LAY MONITORING PROGRAM



FBG Team corraborate tests above and sample plankton

PREFACE

This report contains the findings of a water quality survey of the ponds in the **Pemaquid Watershed Association (PWA)**, Towns of Bremen, Bristol, Damariscotta, Nobelboro and Waldoboro, Maine, conducted in the summer of 1993 by the **Freshwater Biology Group (FBG)** of the University of New Hampshire and the **Pemaquid Watershed Association**.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1993 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGEMENTS

This was the sixth year of participation in the **Lakes Lay Monitoring Program (LLMP)** for the **Pemaquid Watershed Association** monitors. Peter Fischer again undertook the formidable task of coordinating the multi-lake study and acting as the liaison to the **FBG**.

1993 Pemaquid Watershed Association Volunteer Monitors:

Name	Lake Monitored
Scott Giguere -	Biscay Pond
Peter Fischer -	Boyd Pond
David Libby -	Duckpuddle Pond
Albert "Mac" Rogers -	McCurdy Pond
Steve O'Bryan	Paradise Pond
David McLeod	Pemaquid Pond

The **Freshwater Biology Group (FBG)** congratulates the Lay Monitors on the quality of their work, and the time and effort put forth. We encourage other interested members of the **Pemaquid Watershed Association** to continue monitoring during the 1994 season. Financial support for the monitoring effort was provided by the Towns of Bremen, Bristol, Damariscotta and Nobelboro while a grant from the GTE Telephone Company allowed the purchase of three electronic thermometers. Additional support was supplied by the Science Source of Waldoboro, which donated a water sampler to the **Pemaquid Watershed Association**, the Great Salt Bay Sanitary District, which provided lab space and personnel who performed bacteriological analysis, the Mobile Glass Company of Bristol which assisted in equipment repair, and Gilliam's Fish Market in Damariscotta, which acted as a collection point for water quality samples.

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included Roy Clark, Robert Craycraft, Amanda Jamison, Gregory O'Neil, Sean Proll and Jeffrey Schloss. Other **FBG** staff assisting in the fall included Jessica Chappel, Steven Meyer and Marjorie Steele.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Derry Conservation Commission, Dublin Garden Club, Governor's Island Club Inc., Little Island Pond Rod and Gun Club, Meredith Bay Rotary Club, Nashua Regional Planning Commission, The New Hampshire Audubon Society, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Beaver Lake, Berry Bay, Big Island Pond, Bow Lake Camp Owners, Chalk Pond, Chesham Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin Lake, Glines Island, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mascoma Lake, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pea Porridge Pond, Pemaquid Watershed, Perkins Pond, Pleasant Lake, "Silver Lake" (Hollis), "Silver Lake" (Harrisville), "Silver Lake" (Madison), "Silver Lake" (Tilton), Squam Lakes, Lake Sunapee, Sunset Lake, Lake Waukewan, Lake Winona, Wentworth Lake and the towns of Alton, Amherst, Enfield, Hollis, Madison, Meredith, Merrimack, Strafford and Wolfeboro.

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INTRODUCTION

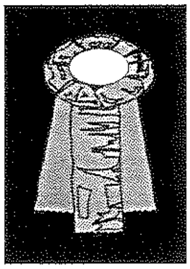
The New Hampshire Lakes Lay Monitoring Program

In this sixteenth year of operation, the **NH Lakes Lay Monitoring Program** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide. The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis systems (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

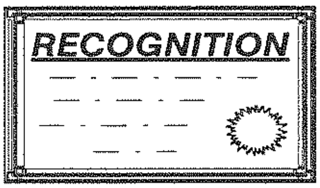
The 1993 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program**. National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America and on the Environmental Network Clearinghouse. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty two states and nine countries (see figure 1)!

Figure 1. NH LLMP Awards and Recognition

AWARDS

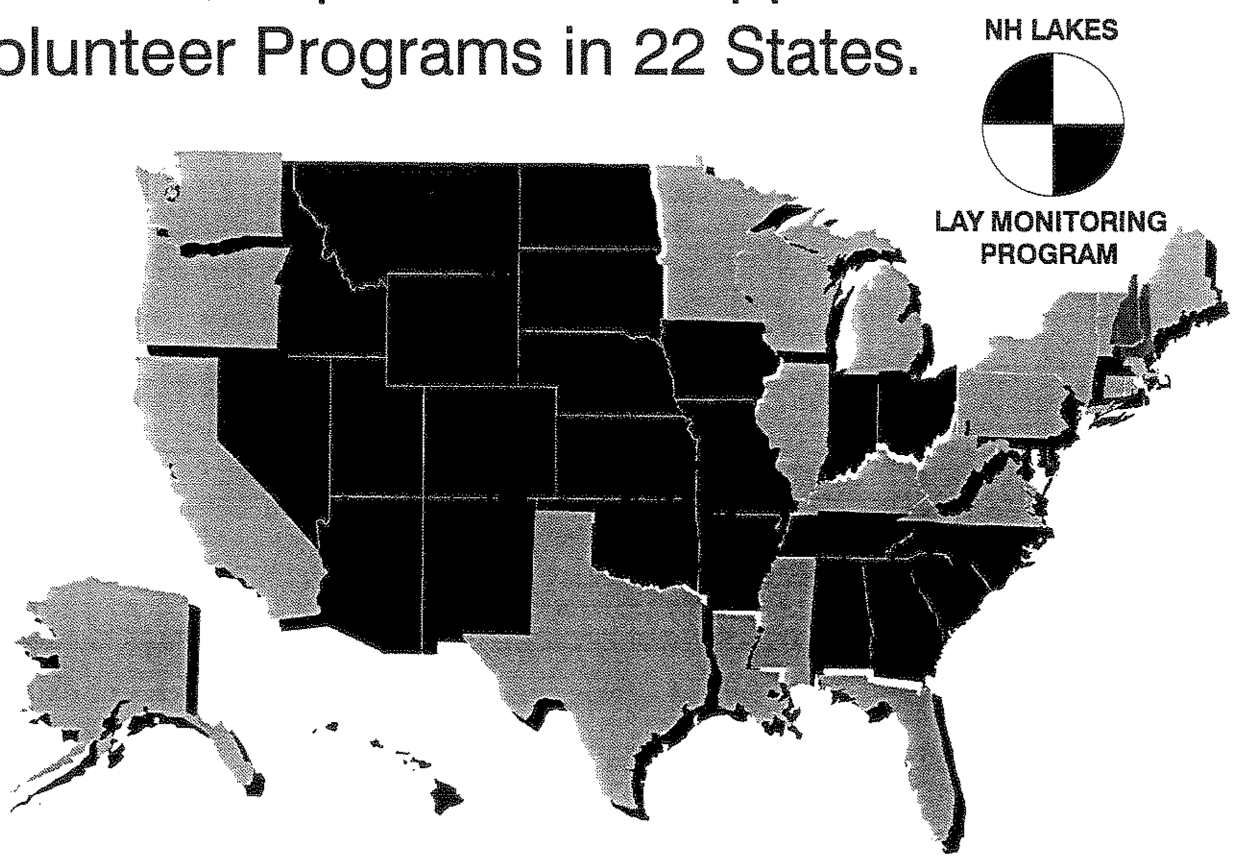


and



1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal on PBS
1991- Renew America Success Award
- Environmental Success Index
- UN Environmental Programme
- Soviet Embassy Reception
- White House Environment Briefing
1992- EPA Administrators Award
- Environmental Exchange Network
1993- NH Lakes Association

NH LLMP Directly Involved with the Initiation, Expansion or Support of Volunteer Programs in 22 States.



Our Fish Condition Program intensive lake survey results have been tabulated, reports went to NH Fish & Game (our sponsor) and to the participating lake associations. Our fish study team is now focusing on the Newfound Lake fishery to determine the effects and results of alewife introduction.

Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For almost a decade and a half, data collected weekly from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

To determine if a change in water quality is occurring, a lake must be sampled on a frequent basis over a substantial amount of time. A poorly designed sampling program may even mislead the investigator away from the actual trend: Consider the hypothetical lake in Figure 2. Sampling only once a year during August from 1982 to 1986 would produce a plot (Fig. 3) suggesting a decrease in eutrophication. The actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling additional times a year for a ten year period (Fig. 2). Frequent monitoring carried out over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). To that end, the lake must establish a long-term data base.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data is collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

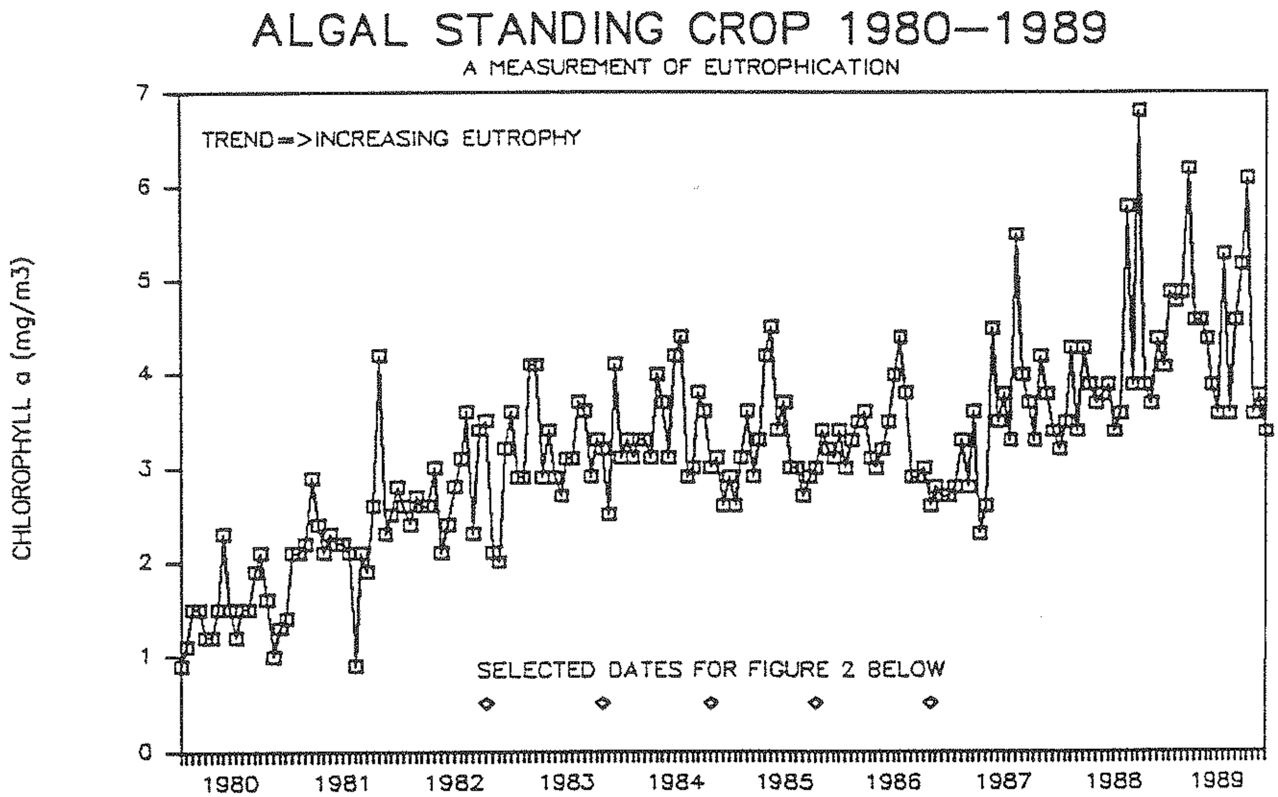


Fig. 2 The upper graph depicts weekly chlorophyll concentrations of a model lake measured weekly during ice-free conditions. The long-term trend is that of increased eutrophication (lake has become "greener"). Diamonds below the curve represent late summer (August) dates the data set was subsampled to create Figure 2.

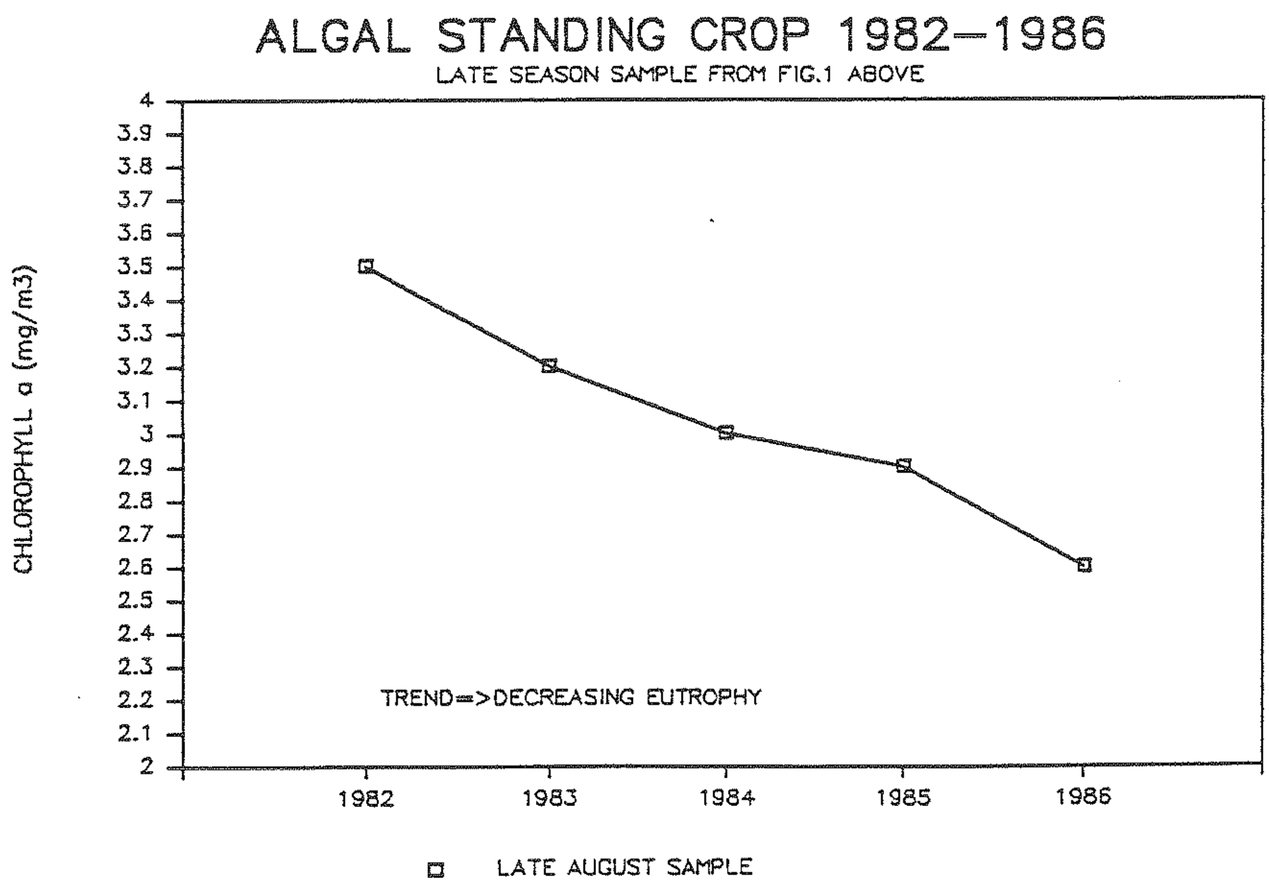


Fig. 3 The lower graph depicts late summer chlorophyll data of the model lake in Figure 1. Note how limited sampling over a five year period suggests a much different trend, that of decreasing eutrophy. Thus, limited sampling can mislead the investigator of long-term trends.

Purpose and Scope of This Study

This was the fifth year that monitoring of Boyd Pond and the sixth year that monitoring of Biscay, Duckpuddle, McCurdy, Paradise and Pemaquid Ponds was undertaken by the **Freshwater Biology Group** and the **Pemaquid Watershed Association** (see figures 4 through 8 for the site locations). The program of sampling was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on one open water deep station in each pond while additional tributary sampling was undertaken early in the season to monitor the nutrient loading at that time and identify potential "problem areas" within the watershed.

The primary purpose of this report is to discuss results of the 1993 monitoring with emphasis on current conditions of Biscay, Boyd, Duckpuddle, McCurdy, Paradise and Pemaquid Ponds including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. Care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various testing facilities and technological improvements in testing.

THE GENERAL SCENARIO - 1993

The Winter of 1992-93 was off to a white start with several major snowstorms occurring in the early months. The accumulated snowpack in many areas resulted in considerable runoff in late March and early April during the spring snowmelt. For those lakes which were monitored early enough, the winter conditions translated into lower alkalinities (buffering capacity) and lower pH levels in the tributary streams. Some lakes demonstrated similar phenomenon when compared to results from a few years back; years with little snow pack. Thus, while many lakes have had steady or even increasing buffering levels for the last few years, a more typical (in terms of what was "normal" for New Hampshire in the last 30 years) snowfall amount this winter indicates that acid rain should still be one of our concerns.

The spring and summer months proved to be dry, once again (1993 was one of the driest summers in the past decade). This generally minimized sediment and nutrient runoff from the surrounding watershed and resulted in continued optimum water quality conditions for most participating **LLMP** lakes. In fact, several lakes recorded record high water clarity (Secchi Disk transparency) in 1993.

Lakes were clearer due to a combination of factors that once again included lower dissolved color compounds (dissolved organic matter from the breakdown of vegetation and soils) washed in from surrounding wetland areas, lower algae growth (measured as chlorophyll *a*) in the surface waters, due to lower nutrient runoff, and lower suspended sediment levels. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes.

As with dissolved color and nutrients, the dry spring and summer season brought less suspended sediment load to many of our streams and lakes. If increased clarity was not the result of decreased dissolved color or chlorophyll *a* levels, than it was likely due to decreased suspended sediment by default. To find out how these water quality indicators inter-relate for your particular lake site, compare the Secchi Disk, chlorophyll *a* and dissolved color graphs enclosed in this report (see figures 15-17, 21-23, 28-30, 36-38, 42-44 and 48-50). Note whether changes in clarity (Secchi Disk depth) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

In addition to limited watershed runoff, the hot and dry weather conditions in the early part of the summer resulted in a low water table. This sometimes translates into less of a chance of septic system failure; minimizing algae and some aquatic plant growth by further limiting nutrient loading. However, some lakes did experience increased aquatic plant and/or algae growth in 1993 which could be the result of a variety of factors: a lower water level and thus a greater surface area exposed to penetrating light (for photosynthesis) occurring simultaneously with a large number of clear and sunny days, as well as, warmer water temperatures (conducive to plant growth). Furthermore, longer water detention times limited water movement and retained nutrients in the shoreline areas following minimal storm events, thus stimulating greater plant and algal growth.

In addition, several lakes experienced "algal blooms" late in the season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column. However, "algal blooms" can also accumulate at the lake bottom as "mats" or the water surface as "scums" and "clouds". All types of "algal blooms" were observed in several participating **LLMP** lakes in 1993. "Algal blooms" are naturally occurring phenomenon and are not necessarily associated with changes in lake productivity, although increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms of varied extent typically occur even in our most pristine lakes late in the fall and early in the spring as a result of lake mixing at those times.

In many lakes, particularly those within the Lakes Region of New Hampshire, cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, or a related species, formed within the weed beds and then drifted freely into shallow areas around the lake. These algae often take advantage of nutrients that leak from particularly active submerged weeds or from bottom areas that have been disturbed by weed removal or other activities. While the summer of 1993 exhibited a general reduction in submerged aquatic plant and algal growth, for reasons described above, there were several reports of increased plant and algal growth.

For some lakes, weather conditions became conducive to the formation of "blooms" of other algae species late in the season when the water temperatures were above average and several storm events followed the extremely dry conditions. This flushed materials (sediment, dissolved color, nutrients) down through the watershed and into the lake. With this sudden inoculation of nutrients followed by improved lake flushing, these blooms tended to occur suddenly, but were generally short lived.

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. Dry summers can result in substantial populations of these algae to develop well out of site of the observer (and even the Secchi Disk!) until they "decide" to surface. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

The **LLMP** will continue to monitor "bloom" phenomenon in 1994 as it can be a sign of the changing land use practices and impacts within the lake watershed that can result in a long-term increase in lake productivity. However, it is possible that these phenomena were signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the atypical weather conditions of this past summer.

As in 1992, a few **NH LLMP** lakes were actually worse off during the 1993 sampling season. These lakes included those more productive lakes in which a good deal of nutrients come internally from sediment release. Lakes with significant nutrient input from septic systems or shoreline fertilization and watering would also have a bad year under the 1993 conditions. Other lakes that fared worse this year were seepage lakes, which are shallow lakes that rely on groundwater (springs) in-flow and out-flow for replenishment and cleansing. With a low water table, these lakes became great "growth chambers" for algae. To see how your lake fared in 1993, relative to the previous years of **LLMP** participation, take a look at the Secchi Disk (Figures 9 and 10) and chlorophyll *a* yearly comparison graphs in this report (Figures 11 and 12). Yearly dissolved color comparisons (Figures 13 and 14) are also included. Fluctuations in the water clarity can be an indication of increased lake productivity but can also be the result of naturally occurring dissolved color concentrations (lakewater color resulting from decaying vegetation in and around the lake). The most impacted areas by dissolved color concentrations are those which are rich in wetland areas such as Duckpuddle Pond and Paradise Pond.

Figure 4. Location of the ponds falling within the Pemaquid Watershed.

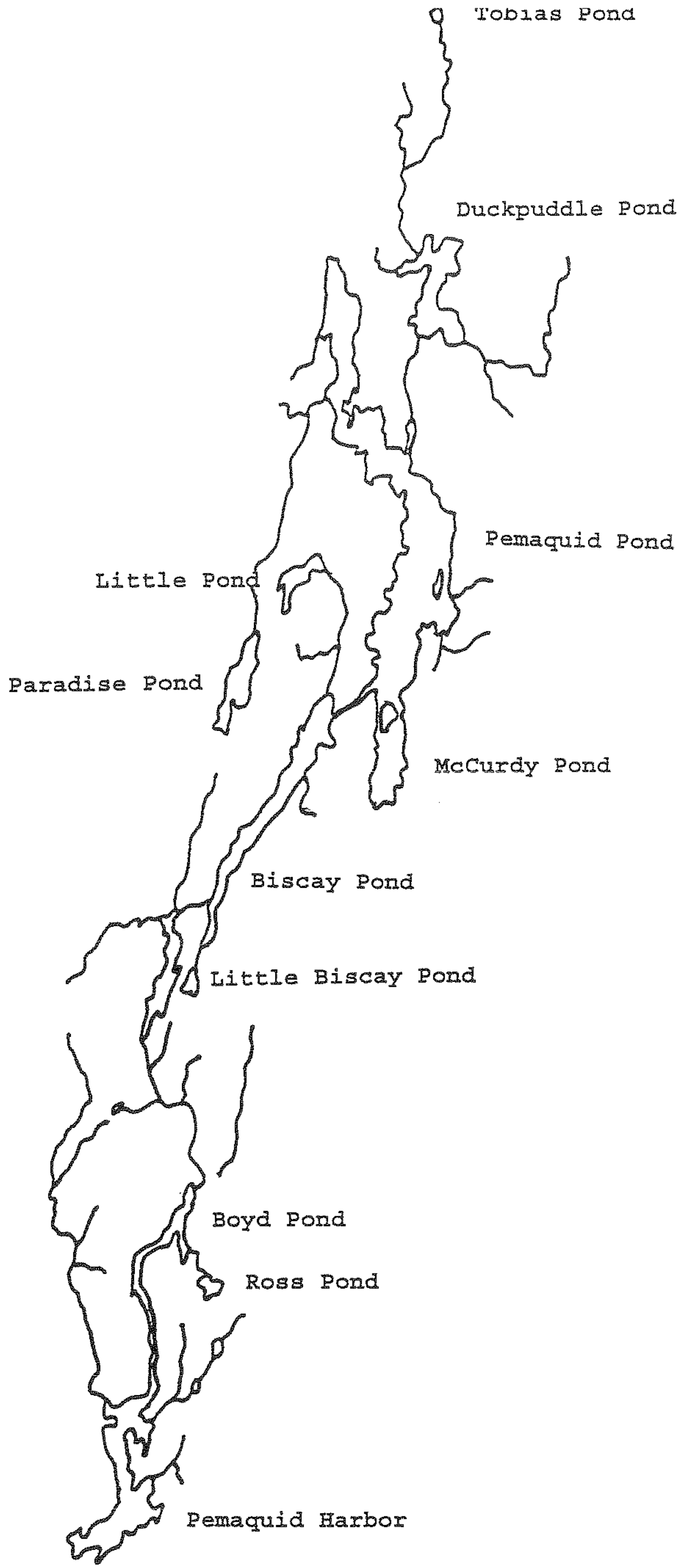

Tobias Pond
Duckpuddle Pond
Pemaquid Pond
Little Pond
Paradise Pond
McCurdy Pond
Biscay Pond
Little Biscay Pond
Boyd Pond
Ross Pond
Pemaquid Harbor

Figure 5. Location of the deep sampling stations from Duckpuddle Pond; Site 1 Basin, and Pemaquid Pond; Sites 1 Basin and 2 Basin. The location of the Glendon Stream sampling station, which feeds Duckpuddle Pond, is also listed.

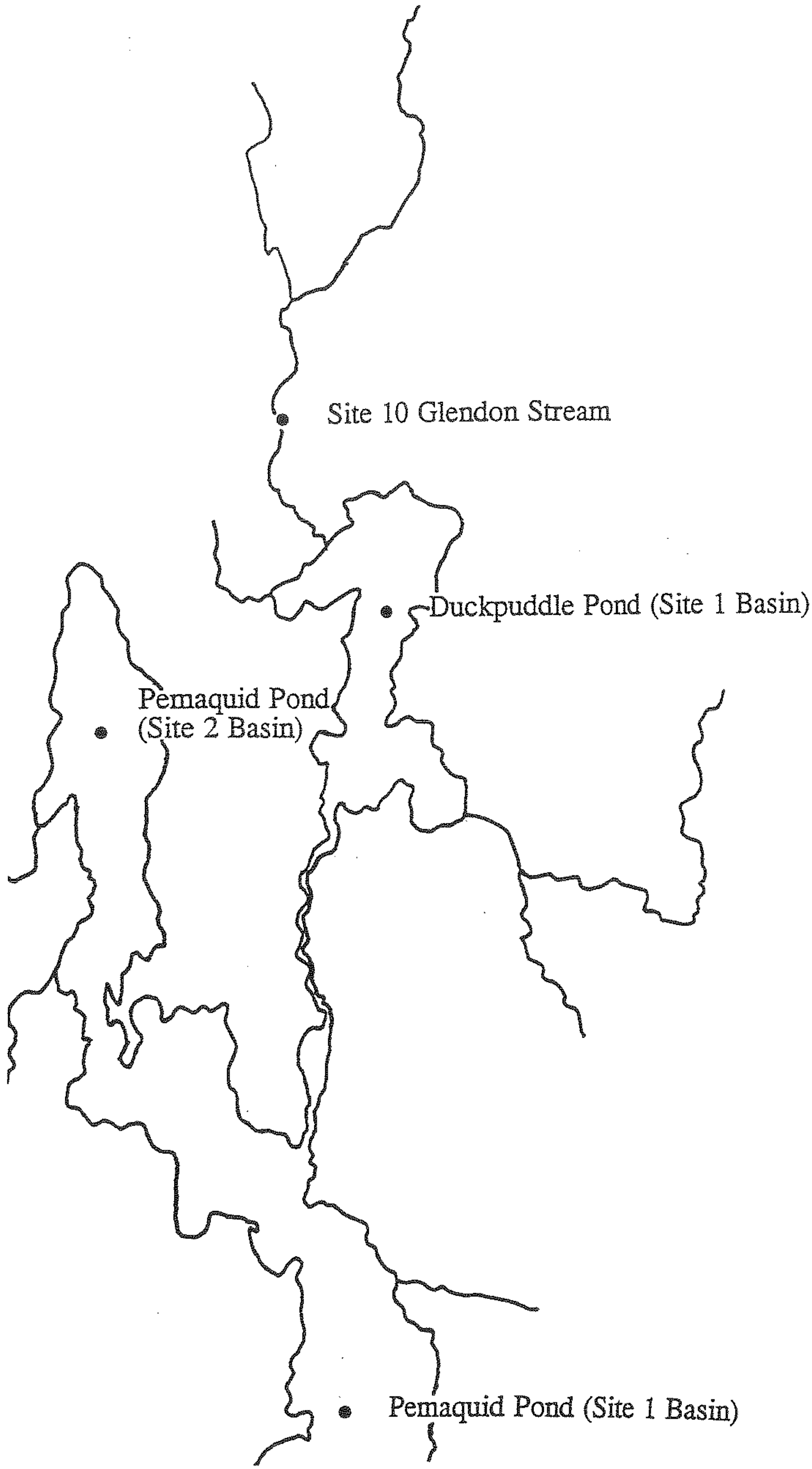

Site 10 Glendon Stream
Duckpuddle Pond (Site 1 Basin)
Pemaquid Pond
(Site 2 Basin)
Pemaquid Pond (Site 1 Basin)

Figure 6. Location of the deep sampling stations from Biscay Pond; Site 1 North, Mccurdy Pond; Site 1 Basin, and Pemaquid Pond; Site 1 Basin. The location of the Biscay Stream (Site 20 Biscay Road) is also included and functions as both the major outlet of Pemaquid Pond and the major inlet to Biscay Pond.

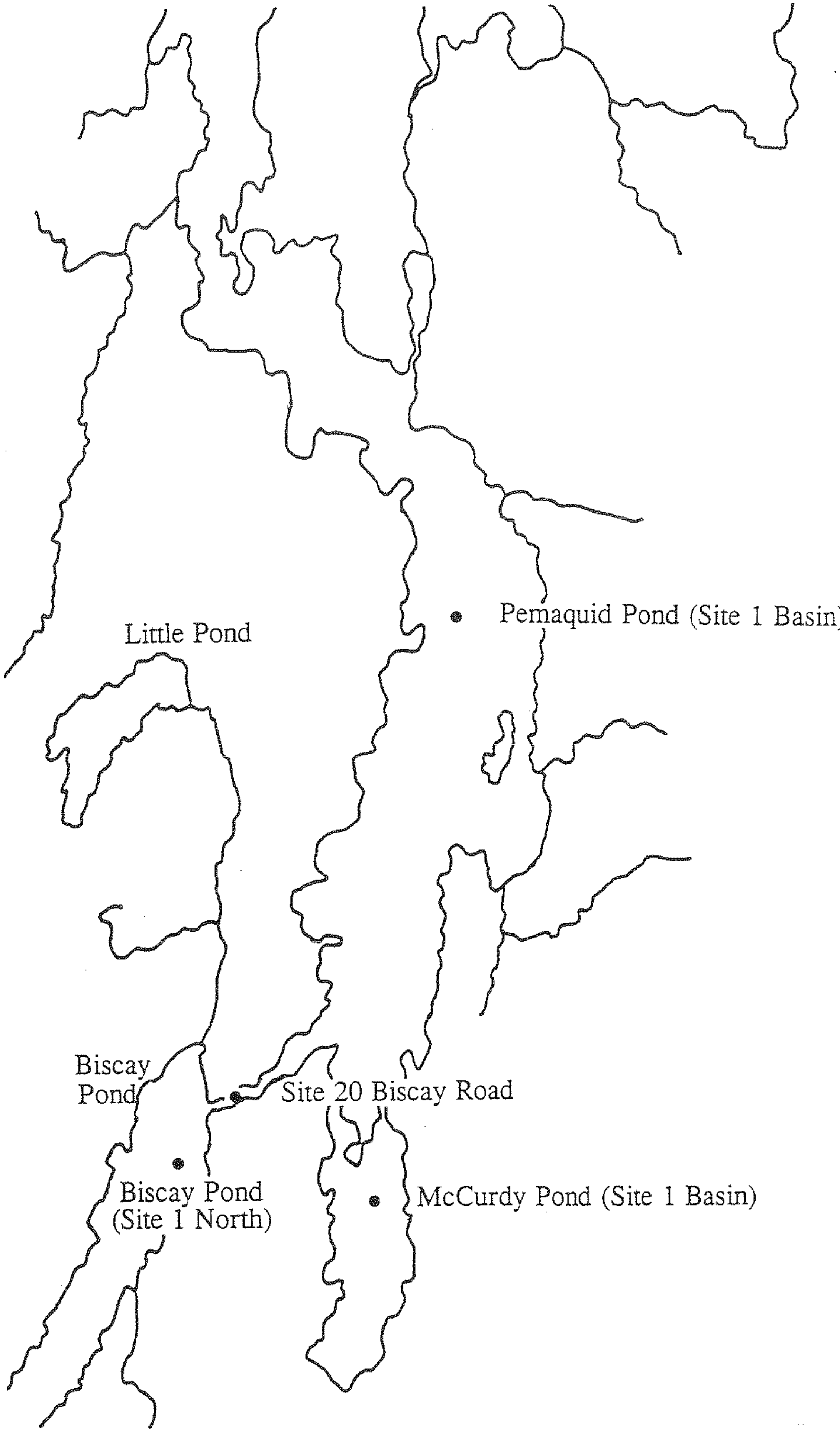

Pemaquid Pond (Site 1 Basin)
Little Pond
Biscay
Pond
Site 20 Biscay Road
Biscay Pond
(Site 1 North)
McCurdy Pond (Site 1 Basin)

Figure 7. Location of the deep sampling stations from Biscay Pond; Site 1 North, McCurdy Pond; Site 1 Basin, and Paradise Pond; Site 2 North. The location of the Pemaquid River (10 Lessner Road) sampling station, which functions as the major outlet of Biscay Pond, is also included.

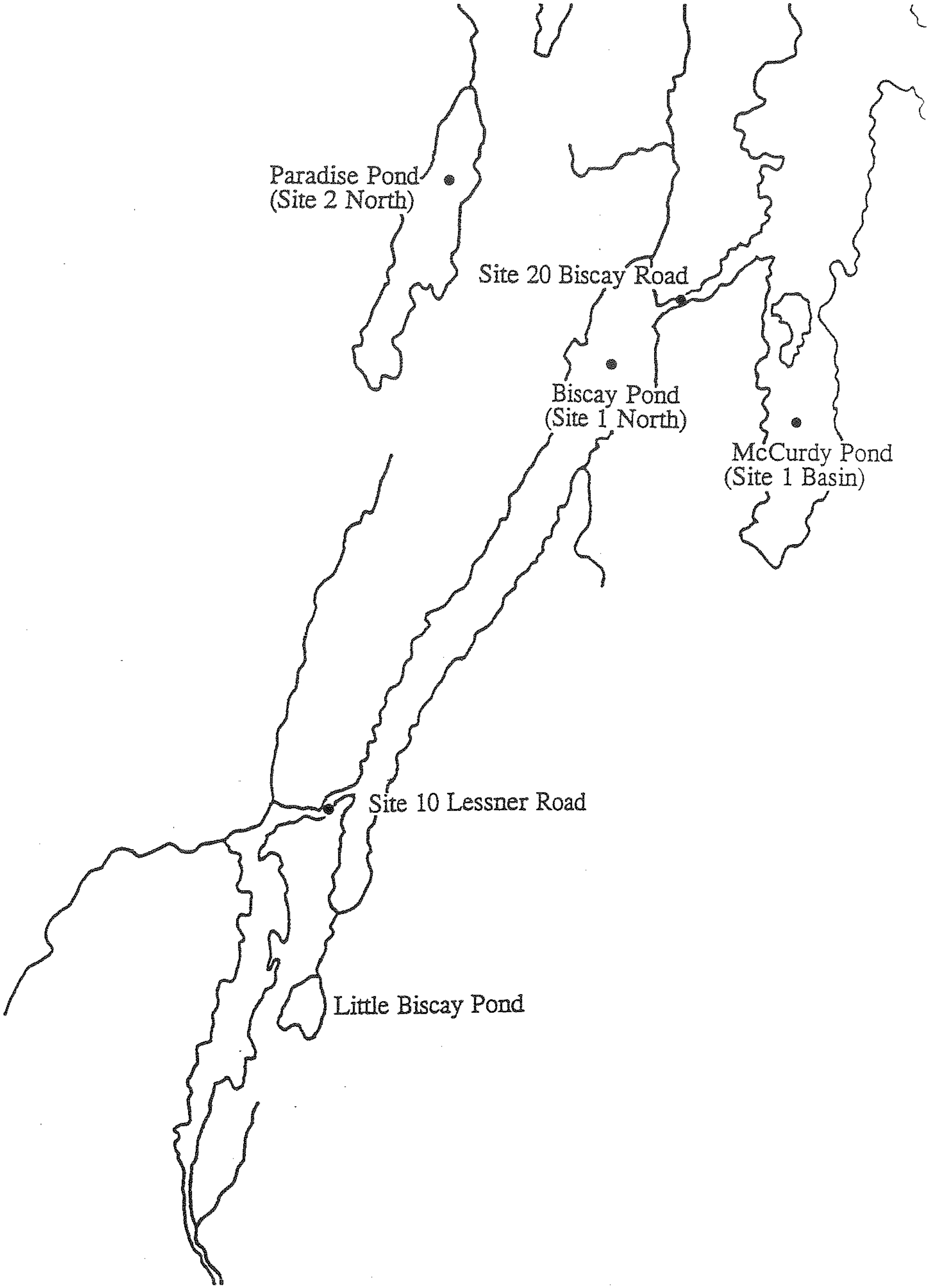

Paradise Pond
(Site 2 North)
Site 20 Biscay Road
Biscay Pond
(Site 1 North)
McCurdy Pond
(Site 1 Basin)
Site 10 Lessner Road
Little Biscay Pond

Figure 8. Location of the deep sampling station from Boyd Pond; Site 1 Center.

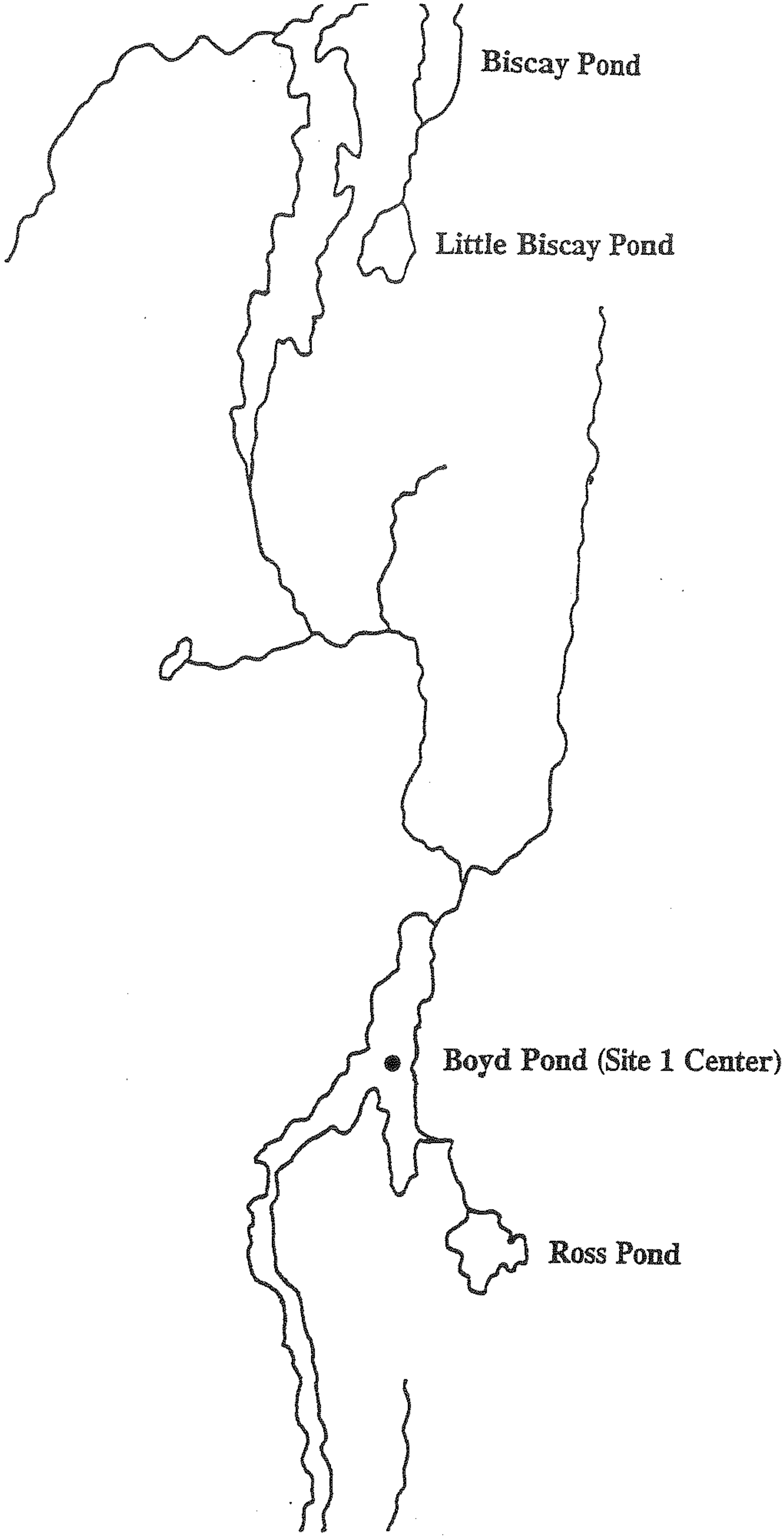
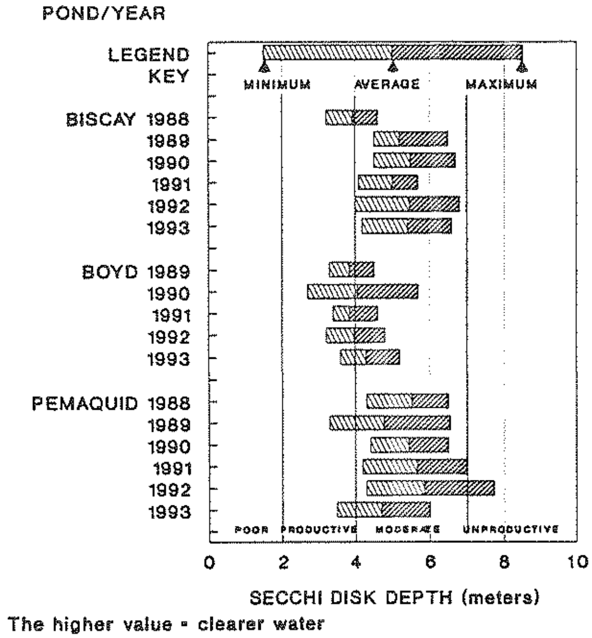

Biscay Pond
Little Biscay Pond
Boyd Pond (Site 1 Center)
Ross Pond

Figure 9. Comparison of the 1993 Biscay Pond, Boyd Pond and Pemaquid Pond lay monitor Secchi Disk Transparency data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the Secchi Disk value, the clearer the lake. Secchi Disk readings are taken to the nearest tenth (0.1) of a meter.

Figure 10. Comparison of the 1993 Duckpuddle Pond and McCurdy Pond lay monitor Secchi Disk Transparency data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the Secchi Disk value, the clearer the lake. Secchi Disk readings are taken to the nearest tenth (0.1) of a meter. Note: the Secchi Disk frequently reached the pondbottom of Paradise Pond before disappearing from view and is thus omitted from the Secchi Disk data comparison.

LAY MONITOR SECCHI DISK DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)



LAY MONITOR SECCHI DISK DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)

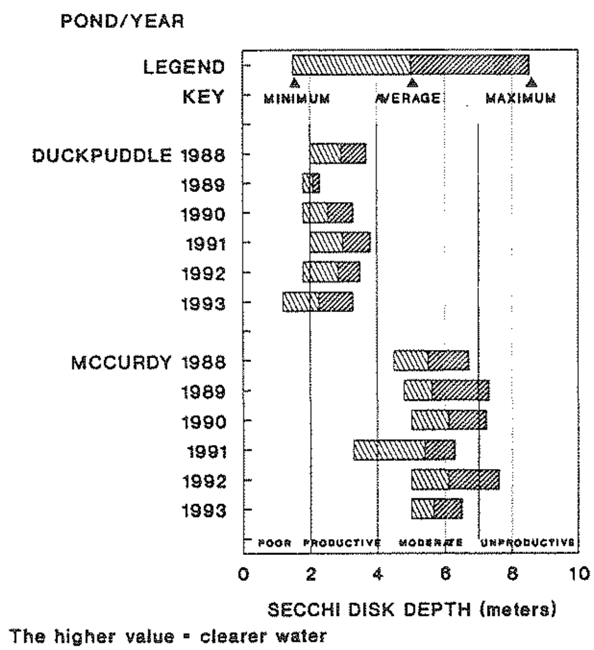
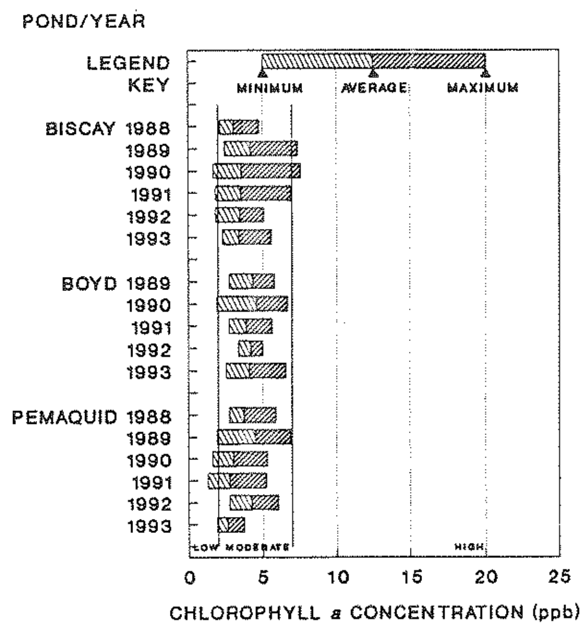


Figure 11. Comparison of the 1993 Biscay Pond, Boyd Pond and Pemaquid Pond lay monitor Chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the chlorophyll *a* concentration, the more algal growth (i.e. greener water).

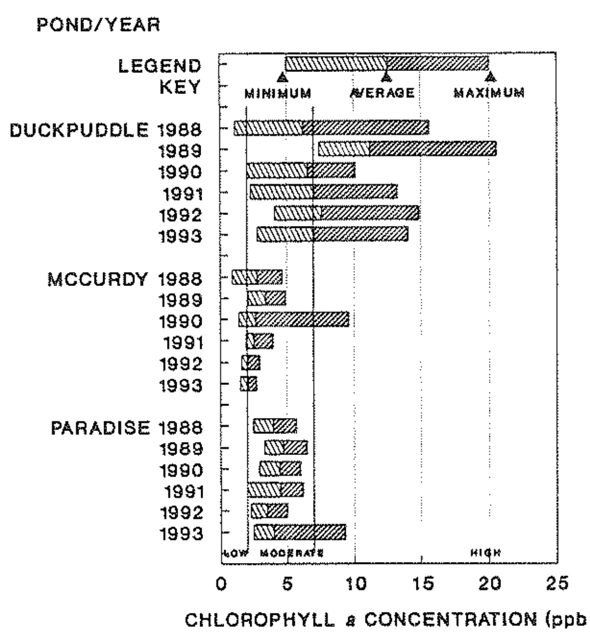
Figure 12. Comparison of the 1993 Duckpuddle Pond, McCurdy Pond and Paradise Pond lay monitor Chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the chlorophyll *a* concentration, the more algal growth (i.e. greener water).

LAY MONITOR CHLOROPHYLL *a* DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)



The higher value = more algae

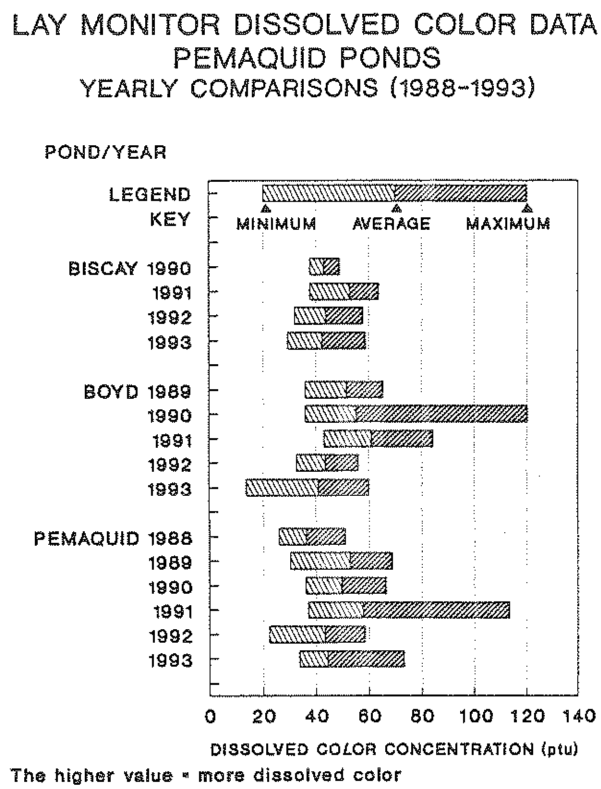
LAY MONITOR CHLOROPHYLL *a* DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)



The higher value = more algae

Figure 13. Comparison of the 1993 Biscay Pond, Boyd Pond and Pemaquid Pond lay monitor Dissolved Color data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the dissolved color concentration, the more colored the water (i.e. more tea colored).

Figure 14. Comparison of the 1993 Duckpuddle Pond, McCurdy Pond and Paradise Pond lay monitor Dissolved Color data with previous yearly data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The higher the dissolved color concentration, the more colored the water (i.e. more tea colored).


LAY MONITOR DISSOLVED COLOR DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)
POND/YEAR
LEGEND
KEY
MINIMUM
AVERAGE
MAXIMUM
BISCAY 1990
1991
1992
1993
BOYD 1989
1990
1991
1992
1993
PEMAQUID 1988
1989
1990
1991
1992
1993
0
20
40
60
80
100
120
140
DISSOLVED COLOR CONCENTRATION (ptu)
The higher value = more dissolved color

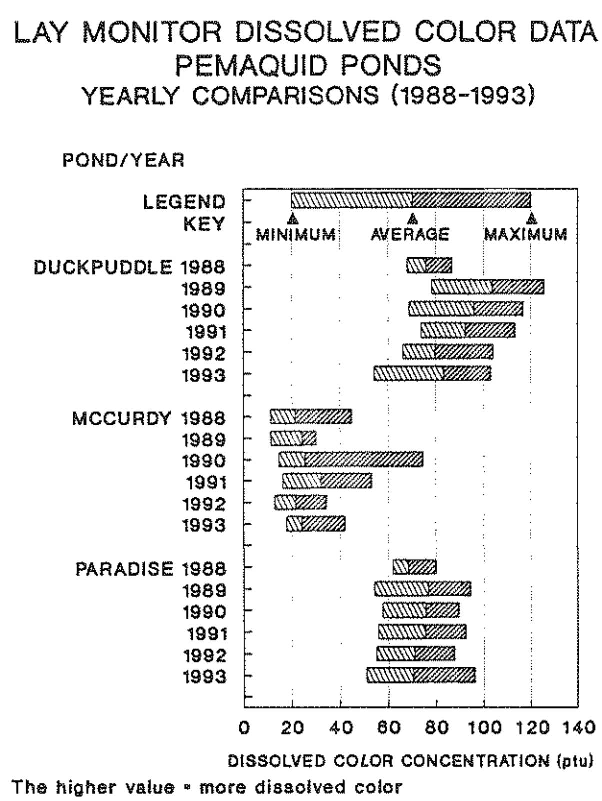

LAY MONITOR DISSOLVED COLOR DATA
PEMAQUID PONDS
YEARLY COMPARISONS (1988-1993)
POND/YEAR
LEGEND
KEY
MINIMUM
AVERAGE
MAXIMUM
DUCKPUDDLE 1988
1989
1990
1991
1992
1993
MCCURDY 1988
1989
1990
1991
1992
1993
PARADISE 1988
1989
1990
1991
1992
1993
0
20
40
60
80
100
120
140
DISSOLVED COLOR CONCENTRATION (ptu)
The higher value = more dissolved color

Table 1. Biscay Pond -- trophic indicators, 1993

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY

Average transparency:	5.4	(1993:	12	values;	4.2	-	6.6	range)
Average chlorophyll:	3.4	(1993:	12	values;	2.3	-	5.6	range)
Average lake phos.:	6.8	(1993:	2	values;	6.4	-	7.1	range)
Average color, 440:	42.4	(1993:	12	values;	29.2	-	58.4	range)
Average trib phos.:	4.2	(1993:	4	values;	2.4	-	6.0	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 North	05/08/1993	5.9	2.5	7.1	---	---	58.4
1 North	05/22/1993	4.4	3.3	---	---	---	48.1
1 North	06/05/1993	4.7	2.9	---	---	---	44.7
1 North	06/20/1993	4.2	2.3	---	---	---	43.8
1 North	07/05/1993	5.7	2.5	---	---	---	43.8
1 North	07/17/1993	5.7	2.8	---	---	---	37.8
1 North	07/31/1993	5.0	4.8	---	---	---	38.7
1 North	08/14/1993	5.4	5.1	---	---	---	40.4
1 North	08/28/1993	5.6	3.7	---	---	---	33.5
1 North	09/12/1993	6.6	2.8	---	---	---	31.8
1 North	09/29/1993	6.5	2.8	---	---	---	58.4
1 North	10/09/1993	5.4	5.6	6.4	---	---	29.2
10 LessRd	03/27/1993	---	---	2.4	---	---	---
10 LessRd	04/24/1993	---	---	5.1	---	---	---
20 Inlet	03/27/1993	---	---	3.1	---	---	---
20 Inlet	04/24/1993	---	---	6.0	---	---	---

<< End of 1993 listing, 14 records >>

BISCAY POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of Biscay Pond was undertaken by the volunteer monitor, Scott Giguere, from May 8 through October 9, 1993 (see table 1 and figures 15-17). Additional tributary nutrient sampling was performed in the spring to assess the impact of the heavy watershed runoff which occurred at that time. The following data summarize the 1993 conditions of Biscay Pond, and when applicable, incorporate historical data into the interpretation. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) Water transparency at Biscay Pond was representative of a moderately productive lake according to the criteria employed by the **Maine Department of Environmental Protection (DEP)**. The seasonal water transparency average of 5.4 meters (17.6 feet) is similar to the 1992 Secchi Disk transparency (5.5 meters) and remains well within the range of historical readings.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) in the surface waters of Biscay Pond were moderate in 1993. The seasonal chlorophyll *a* concentration averaged 3.4 milligrams per cubic meter (3.4 mg m^{-3} equivalent to 3.4 parts chlorophyll *a* per billion parts water) at Site 1 North which falls within the **Maine DEP** criteria for a moderately productive lake.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for Biscay Pond were moderate to high in 1993, 42.4 platinate color units (ptu).

4) Total phosphorus samples (generally considered the limiting nutrient for plant growth in freshwater systems), collected from the pond inlets early in the season (March

27 and April 24) and from the in-lake sampling station early (May 8) and again late in the season (October 9), remained within the ranges typical of a borderline unproductive/moderately productive lake (see table 1 for the 1993 total phosphorus results). The 1993 phosphorus concentrations are within historical phosphorus concentrations recorded by the **NH LLMP** and the **Maine DEP**.

5) The pond's alkalinity (buffering capacity against acid precipitation), recorded by the **Maine DEP** (1981, 1983, 1988 and 1990) is moderate, and sufficient to resist fluctuations in pH, caused by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor indicate the upper mixed layer of water extended to about 5 meters during the 1993 season, typical of a northern temperate lake. Historical oxygen data, collected by the **Maine DEP** (1981, 1982, 1988 and 1990), indicate oxygen concentrations are reduced in the bottom (hypolimnetic) waters of Biscay Pond during thermal stratification. Low hypolimnetic oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic vegetation) and external (i.e. leaf litter from watershed runoff) sources.

7) For all measurements considered and averaged for the season, Biscay Pond is classified as a moderately productive, mesotrophic lake.

8) Water quality data collected from the Biscay Pond deep sampling station (representative of the average pond conditions) between 1988 and 1993 indicate variable seasonal average chlorophyll *a* and Secchi Disk levels over the aforementioned time span (see figures 18-20 and Appendix A). That is to say, no distinct long term water quality trends are discernable at this time. However, yearly water quality data indicate the lowest Secchi Disk transparencies typically occur early in the season, likely the result of elevated sedimentation into the pond at the time, while additional short term water quality

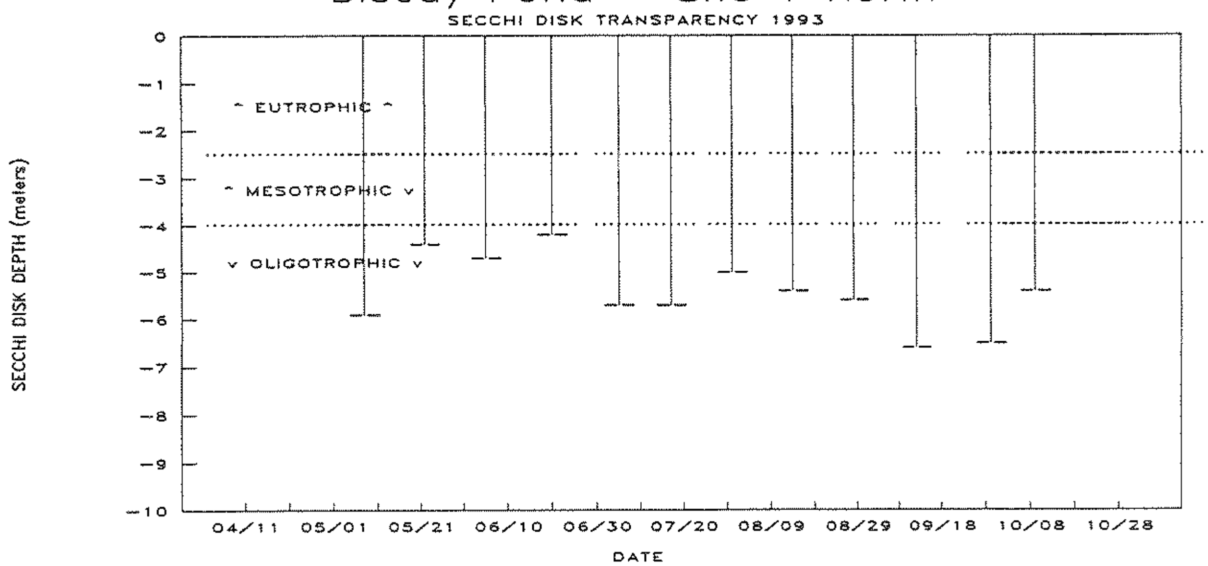
perturbations have been documented later in the sampling season (i.e. reduced water clarities, elevated chlorophyll *a* and phosphorus concentrations). These short term water quality perturbations are often a part of the natural cycling of the pond (variations in productivity through the seasons), but can also be an early "warning sign" of the ponds response to improper land use practices within the watershed. If localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the lake and/or a watershed survey to locate potential problem areas. We can than expand, or revise, the monitoring program to address these more localized regions if the need exists.

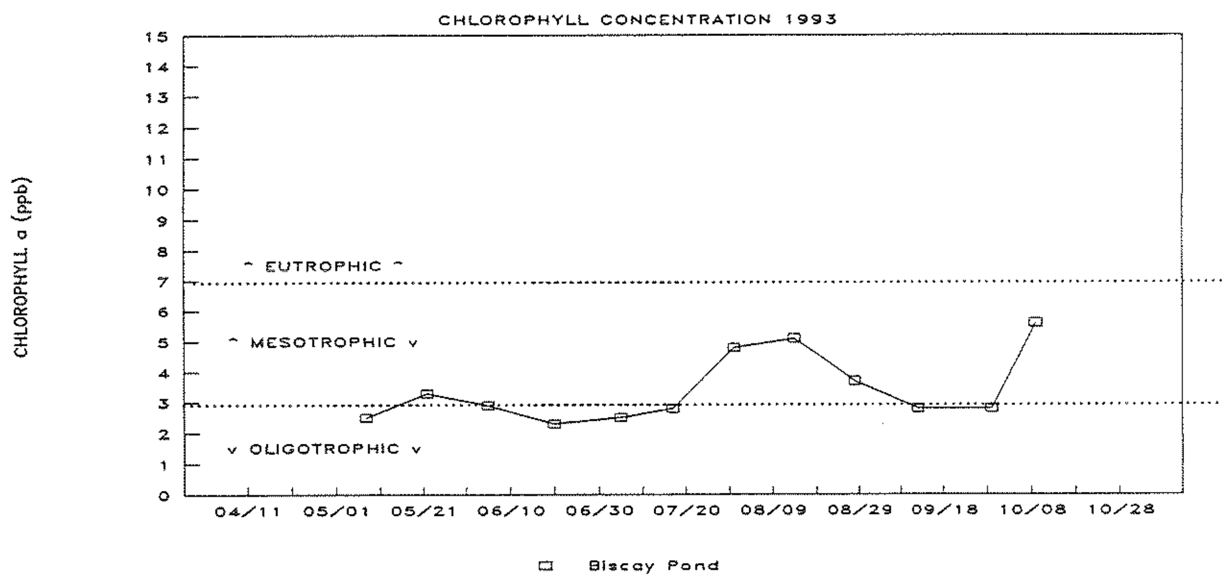
Figure 15. Biscay Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 North. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 16. Biscay Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 North. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 17. Biscay Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 North. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

Biscay Pond — Site 1 North





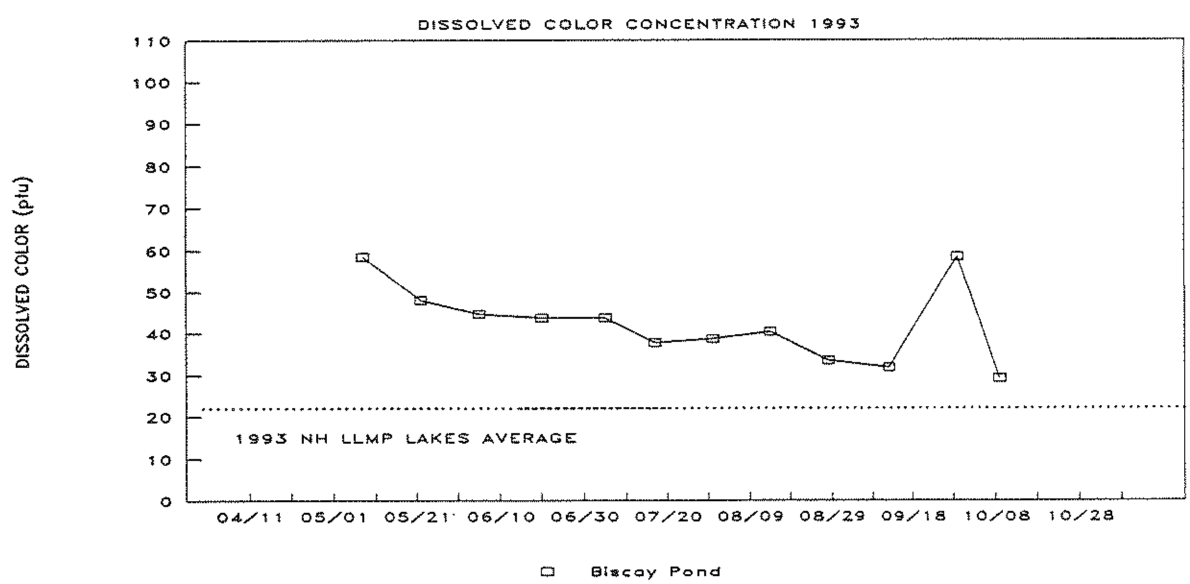


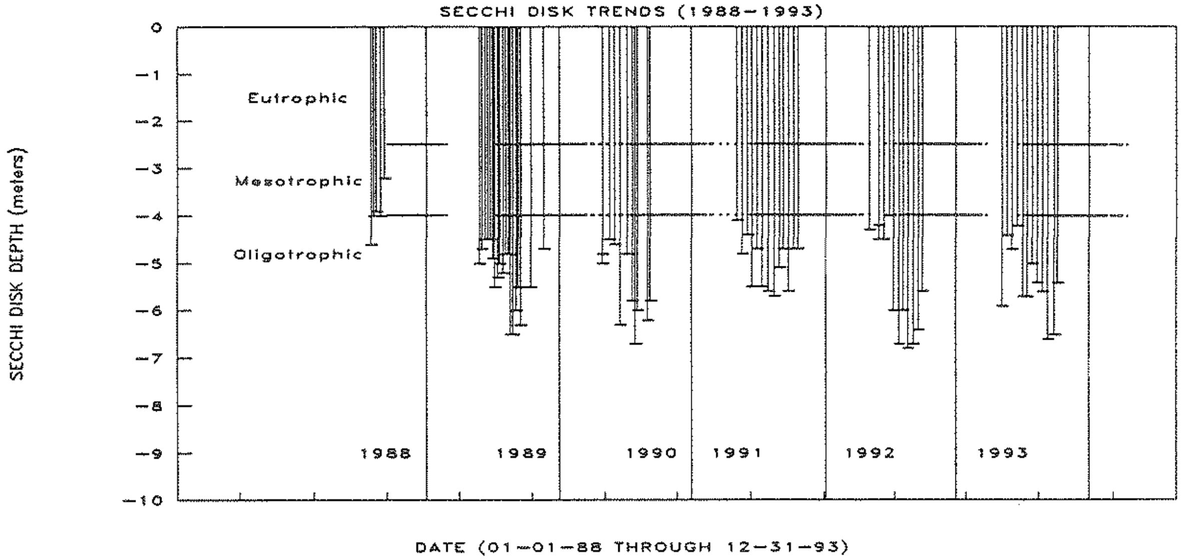
Figure 18. Biscay Pond, 1988-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 North. The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 19. Biscay Pond, 1988-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 North. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 20. Biscay Pond, 1988-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 North. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.

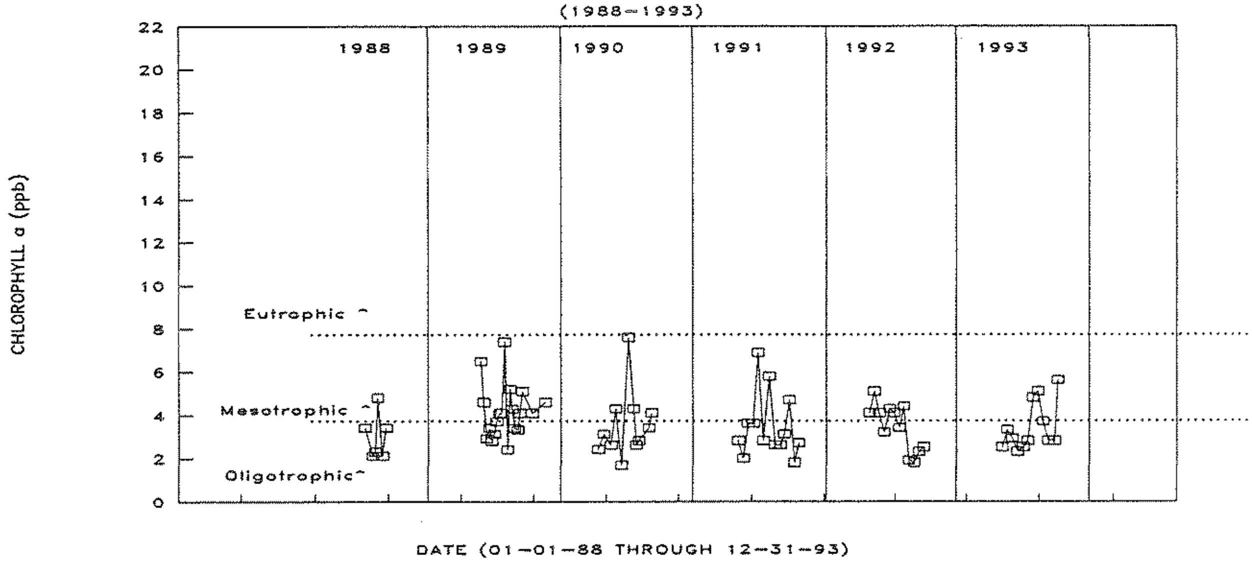
BISCAY POND

SECCHI DISK TRENDS (1988–1993)



BISCAY POND — CHLOROPHYLL a TRENDS

(1988–1993)



BISCAY POND — DISSOLVED COLOR TRENDS

(1989–1993)

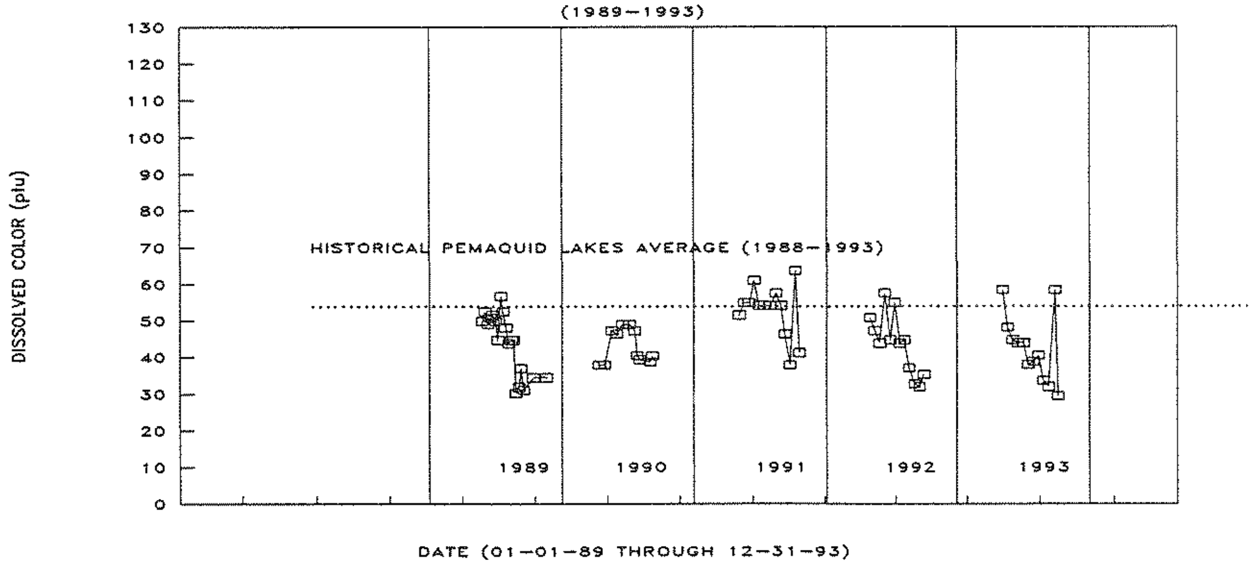


Table 2. **Boyd Pond -- trophic indicators, 1993**

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY

Average transparency:	4.3	(1993:	11	values;	3.6	-	5.2	range)
Average chlorophyll:	4.0	(1993:	10	values;	2.5	-	6.6	range)
Average lake phos.:	9.5	(1993:	2	values;	7.5	-	11.5	range)
Average alk (gray):	3.6	(1993:	1	values;	3.6	-	3.6	range)
Average alk (pink):	4.4	(1993:	1	values;	4.4	-	4.4	range)
Average color, 440:	40.8	(1993:	10	values;	13.7	-	60.1	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Center	05/09/1993	4.5	2.5	7.5	3.6	4.4	56.7
1 Center	06/05/1993	3.8	3.6	---	---	---	54.1
1 Center	06/20/1993	4.1	2.7	---	---	---	60.1
1 Center	07/05/1993	4.8	3.6	---	---	---	46.4
1 Center	07/17/1993	3.9	4.7	---	---	---	44.7
1 Center	08/01/1993	4.3	5.5	---	---	---	13.7
1 Center	08/15/1993	4.8	3.3	---	---	---	36.1
1 Center	08/29/1993	5.2	4.3	---	---	---	33.5
1 Center	09/12/1993	4.3	3.6	---	---	---	31.8
1 Center	10/03/1993	4.0	6.6	---	---	---	30.9
1 Center	10/10/1993	3.6	---	11.5	---	---	---

<< End of 1993 listing, 11 records >>

BOYD POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of Boyd Pond was undertaken by the volunteer monitor, Peter Fischer, from May 9 through October 10, 1993 (see table 2 and figures 21-23). The following data summarize the 1993 conditions of Boyd Pond, and when applicable, incorporate historical data into the interpretation. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) Water transparency at Boyd Pond was representative of a moderately productive lake according to the criteria employed by the **Maine Department of Environmental Protection (DEP)**. The seasonal water transparency average of 4.3 meters (14.0 feet) is comparable to the 1992 seasonal average water clarity of 4.0 meters.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) for the surface waters of Boyd Pond were moderate in 1993. The seasonal chlorophyll *a* concentration averaged 4.0 milligrams per cubic meter (4.0 mg m^{-3} equivalent to 4.0 parts chlorophyll *a* per billion parts water) at Site 1 Center which falls within the **Maine DEP** criteria for a moderately productive lake. The seasonal average chlorophyll *a* concentration is one of the lower seasonal averages on record (i.e. there is less microscopic plant growth). However, a chlorophyll reading of 6.6 ppb in October matched the highest reading on record and is indicative of an algal "bloom" at that time. An algal "bloom", such as this, is common in lakes which accumulate nutrients in the bottom waters during summer stratification. The mixing of the lake in the fall allows these previously "trapped" nutrients to circulate and thus stimulate algal growth.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for Boyd Pond were moderate to high in 1993, 40.8 platinate color units (ptu). The highest dissolved color concentrations occurred early in the season (May and June) which is likely the result of the flushing of wetland areas (located north of the pond) into the pond.

4) Total phosphorus samples (generally considered the limiting nutrient for microscopic plant growth in freshwater systems), collected from the in-lake sampling station early (May 9) and late (October 10) in the season, remained within the ranges typical of a borderline unproductive/moderately productive lake (see table 2 for 1993 total phosphorus results). The 1993 phosphorus concentrations are within historical phosphorus concentrations recorded by the **NH LLMP** and the **Maine DEP**. Higher nutrient concentrations were observed late in the season and likely contributed to the elevated algal (chlorophyll *a*) levels at that time.

5) The pond's alkalinity (buffering capacity against acid precipitation), measured by the **Maine DEP** in 1990, is moderate, and sufficient to resist fluctuations in pH, induced by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor revealed the upper mixed layer of water extended to about 5 meters during the 1993 season, typical of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP**, indicate oxygen concentrations are reduced in the bottom (hypolimnetic) waters of Boyd Pond during thermal stratification. Low hypolimnetic oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic vegetation) and external (i.e. leaf litter from watershed runoff) sources.

7) For all measurements considered and averaged for the season, Boyd Pond is classified as a moderately productive mesotrophic lake.

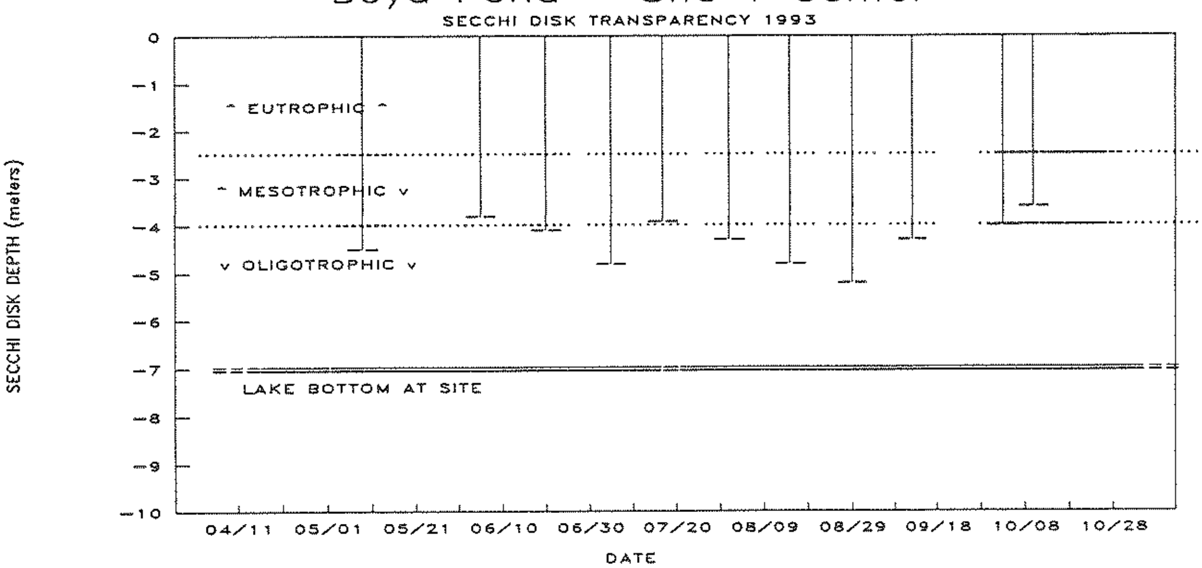
8) Water Quality data collected from the Boyd Pond deep sampling station (representative of the average pond conditions) between 1989 and 1993 indicate relatively constant yearly average chlorophyll *a* and Secchi Disk levels over the aforementioned time span (see figures 24-26 and Appendix A), however, the seasonal chlorophyll *a* and Secchi Disk measurements indicate a higher degree of variability. That is to say, while the yearly average water quality readings from Boyd Pond remained relatively constant between 1989 and 1993 (i.e. no definitive water quality trend), large seasonal fluctuations have been documented. While data collected from the deep sampling station, Site 1 Center, indicates relatively stable water quality measurements over the past five years, more localized problems (i.e. failing and improperly installed septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) might be overlooked in the shallows and in more embayed areas of Boyd Pond. If such problem areas are a concern, we recommend performing a shoreline survey of the lake and/or a watershed survey to locate the potential problem areas within the watershed. We can than expand the monitoring program to investigate these more localized regions if the need exists.

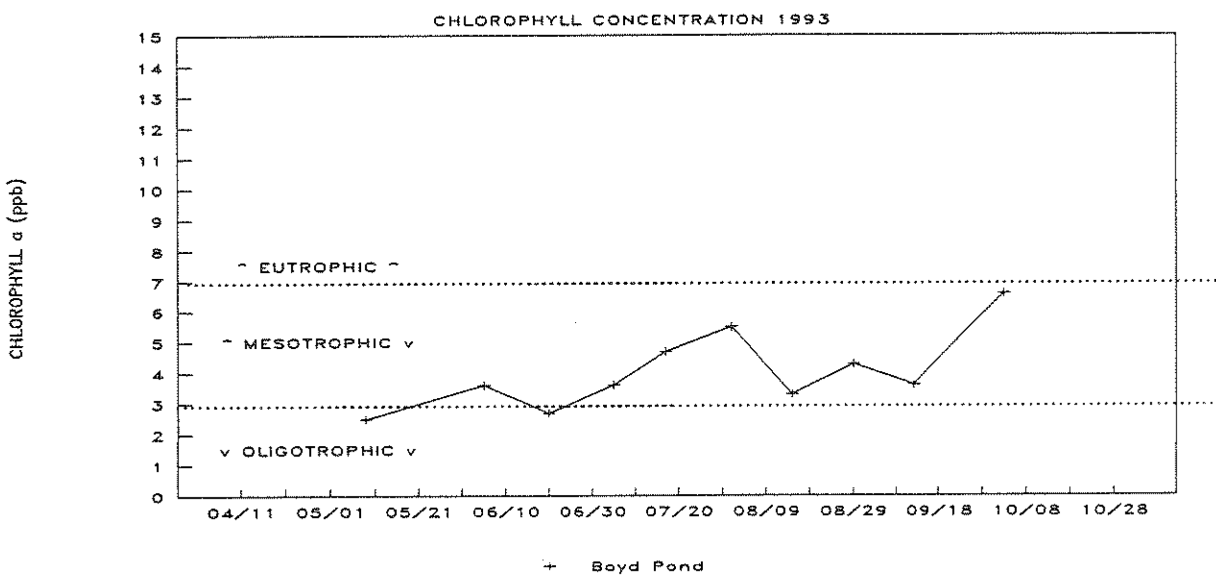
Figure 21. Boyd Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Center. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum depth at the site.

Figure 22. Boyd Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Center. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 23. Boyd Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Center. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

Boyd Pond — Site 1 Center





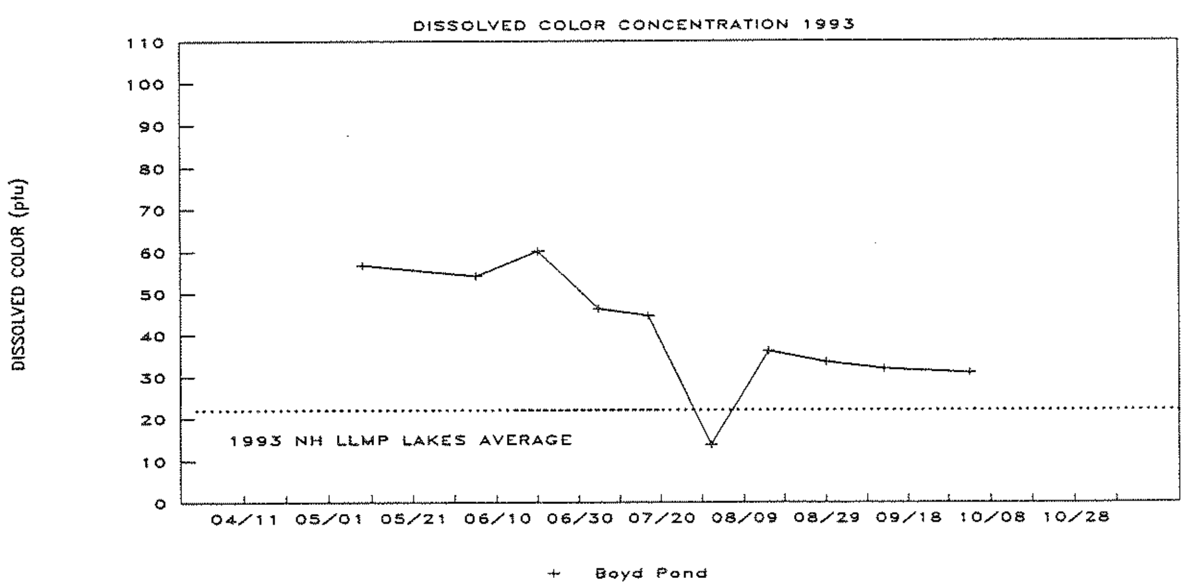
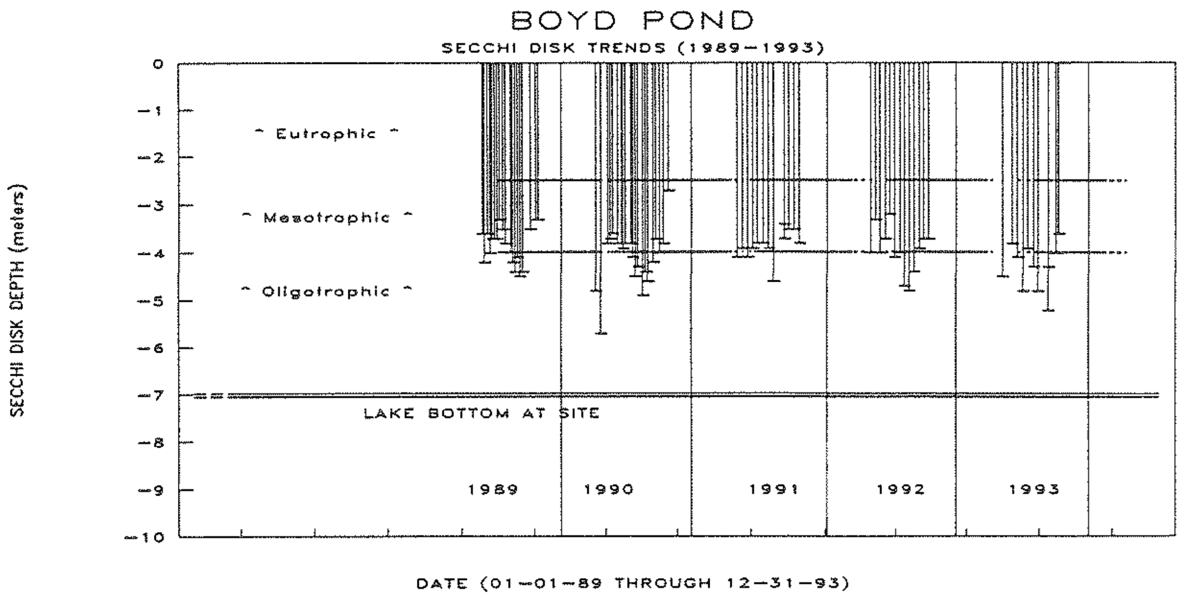
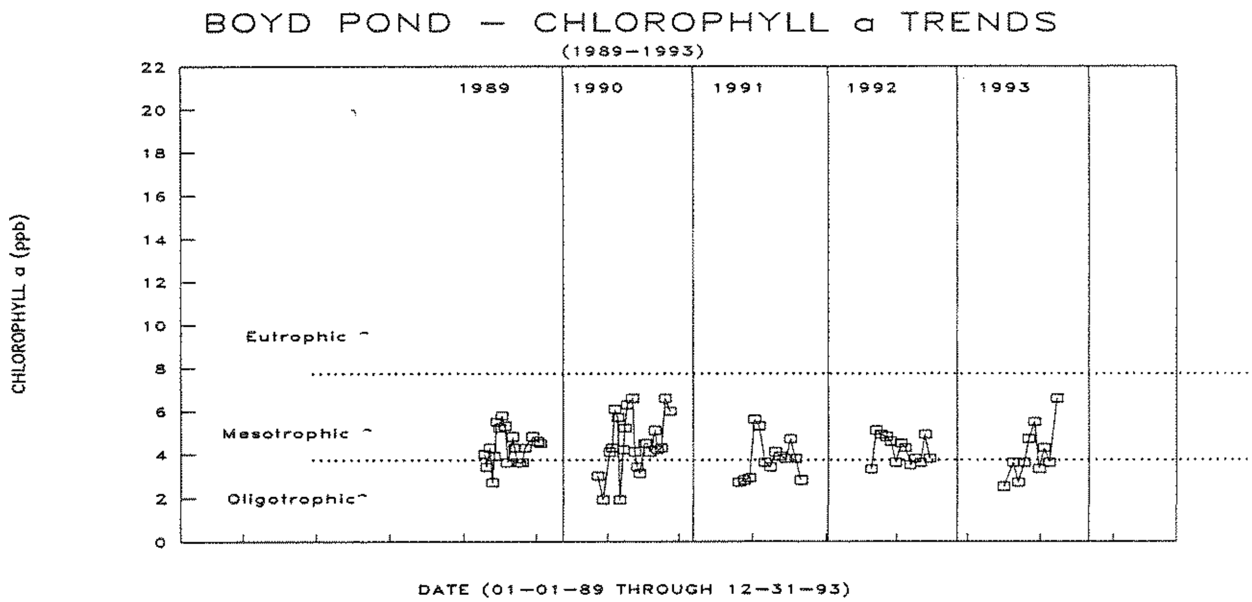


Figure 24. Boyd Pond, 1989-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Center. The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling. The maximum site depth is also included and is denoted by the double solid horizontal line.

Figure 25. Boyd Pond, 1989-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Center. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 26. Boyd Pond, 1989-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Center. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.


BOYD POND
SECCHI DISK TRENDS (1989–1993)
SECCHI DISK DEPTH (meters)
^ Eutrophic ^
^ Mesotrophic ^
^ Oligotrophic ^
LAKE BOTTOM AT SITE
1989
1990
1991
1992
1993
DATE (01–01–89 THROUGH 12–31–93)


BOYD POND – CHLOROPHYLL a TRENDS
(1989–1993)
CHLOROPHYLL a (ppb)
1989
1990
1991
1992
1993
Eutrophic ^
Mesotrophic ^
Oligotrophic^
DATE (01–01–89 THROUGH 12–31–93)

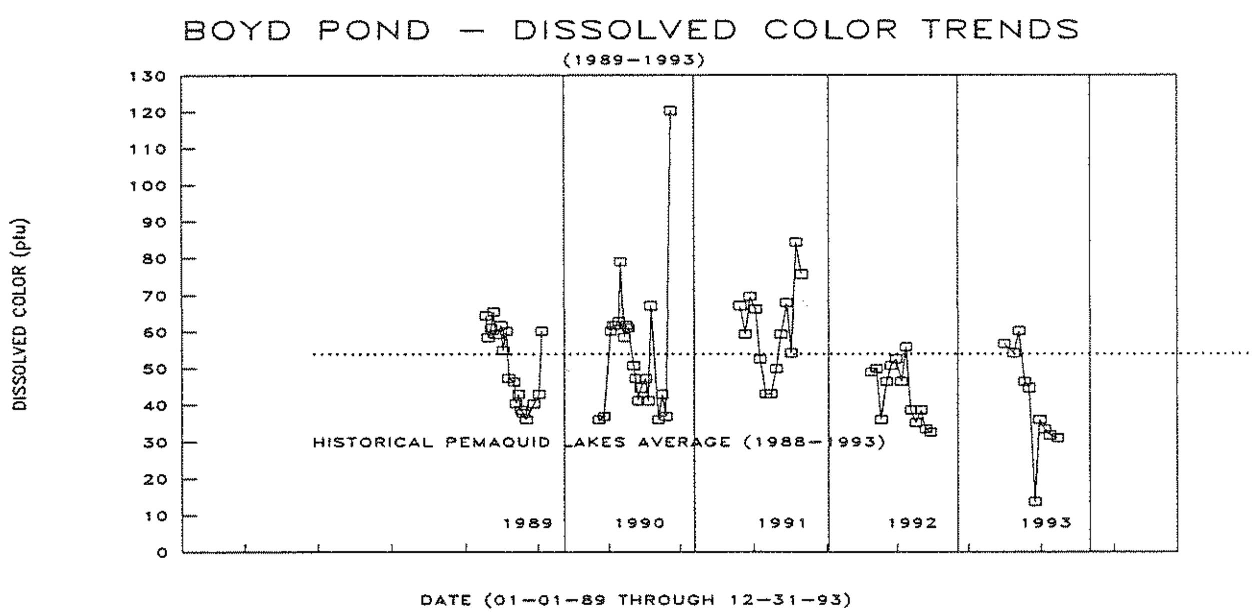

BOYD POND – DISSOLVED COLOR TRENDS
(1989–1993)
DISSOLVED COLOR (ptu)
HISTORICAL PEMAQUID LAKES AVERAGE (1988–1993)
1989
1990
1991
1992
1993
DATE (01–01–89 THROUGH 12–31–93)

Table 3. Duckpuddle Pond -- trophic indicators, 1993

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY

Average transparency:	2.3	(1993:	11	values;	1.2	-	3.3	range)
Average chlorophyll:	7.0	(1993:	11	values;	2.8	-	14.0	range)
Average lake phos.:	26.0	(1993:	2	values;	22.9	-	29.1	range)
Average alk (gray):	7.3	(1993:	7	values;	5.7	-	8.2	range)
Average alk (pink):	8.5	(1993:	7	values;	7.8	-	9.3	range)
Average color, 440:	83.0	(1993:	11	values;	54.1	-	103.1	range)
Average trib phos.:	45.3	(1993:	3	values;	24.0	-	61.1	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	05/16/1993	2.5	2.8	29.1	---	---	90.2
1 Basin	05/31/1993	2.5	5.9	---	---	---	94.5
1 Basin	06/13/1993	2.3	5.1	---	---	---	100.5
1 Basin	06/27/1993	2.5	4.6	---	---	---	91.1
1 Basin	07/11/1993	2.8	3.6	---	5.7	7.8	86.8
1 Basin	07/25/1993	3.3	5.5	---	7.5	8.7	54.1
1 Basin	08/08/1993	2.3	7.1	---	7.4	8.0	76.5
1 Basin	08/22/1993	2.5	7.3	---	7.2	8.2	76.5
1 Basin	09/12/1993	1.5	14.0	---	8.0	9.0	73.9
1 Basin	10/03/1993	1.2	8.0	---	---	---	103.1
1 Basin	10/24/1993	1.7	13.3	22.9	---	---	66.1
10 GlenStr	03/27/1993	---	---	24.0	---	---	---
10 GlenStr	04/18/1993	---	---	50.9	7.4	8.4	---
10 GlenStr	04/24/1993	---	---	61.1	8.2	9.3	---

<< End of 1993 listing, 14 records >>

DUCKPUDDLE POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of Duckpuddle Pond was undertaken by the volunteer monitor, David Libby, from May 16 through October 24, 1993 (see table 3 and figures 28-30). Additional sampling of the Glendon Stream Inlet was performed in the spring to assess the impact of the heavy watershed runoff which occurred at that time. The following data summarize the 1993 conditions of Duckpuddle Pond, and when applicable, incorporate historical data into the interpretation. Initial findings of a Glendon Stream phosphorus survey, conducted on March 27, 1994, is also displayed in figure 35 of this report. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) Water transparency at Duckpuddle Pond was representative of a productive lake according to the criteria employed by the **Maine Department of Environmental Protection (DEP)**. The seasonal average water transparency of 2.3 meters (7.5 feet) was at its lowest level since 1989; at which time the water clarity averaged 2.1 meters for the season.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) for the surface waters of Duckpuddle Pond were moderate to high in 1993. The seasonal chlorophyll *a* concentration averaged 7.0 milligrams per cubic meter (7.0 mg m^{-3} equivalent to 7.0 parts chlorophyll *a* per billion parts water) at Site 1 Basin which falls within the **Maine DEP** criteria for a moderately to highly productive lake. An increase in chlorophyll *a* (algal) concentrations, late in the season, suggests an influx of nutrients which is might be due to the circulation of nutrients from the deeper waters (internal nutrient loading), but can also be the result of nutrient runoff from agricultural practices,

faulty or improperly constructed septic systems as well as applications of fertilizers to residential lawns.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for Duckpuddle Pond were high in 1993, 83.0 platinate color units (ptu). The high color levels observed in Duckpuddle Pond have a strong impact on the water quality of the pond. Higher dissolved color concentrations were measured early in the season (May and June), relative to the latter months, which is likely the result of the flushing of wetland areas (located around the pond) into the lake at that time. These areas filter out organic matter before reaching the pond and tend to be highly colored as a result of the breakdown of this accumulated material. A dissolved color peak occurred late in the season, October 3, which is likely the result of the flushing of the surrounding wetland areas following a storm event at that time.

4) Total phosphorus samples (generally considered the limiting nutrient for microscopic plant growth in freshwater systems), collected from the Glendon Stream Inlet were high when sampled on March 27, April 18 and April 24, with concentrations of 24.0 ppb, 50.9 ppb and 61.1 ppb, respectively. High phosphorus levels were also noted in the lake on May 16 (29.1 ppb) and again on October 24 (22.9 ppb) (see table 3 for 1993 total phosphorus results). All phosphorus samples collected from Duckpuddle Pond in 1993 exceeded the concentration of 13 ppb considered the boundary between moderately and highly productive lakes by the **Maine DEP**. Additionally, the 1993 phosphorus concentrations are greater than the typical phosphorus concentrations recorded by the **NH LLMP** and the **Maine DEP**.

5) The pond's alkalinity (buffering capacity against acid precipitation), recorded by the volunteer monitor, averaged 8.2 units which is about 4 units less than the previous levels

recorded by the **Maine DEP** (11.0 units in 1981 and 12.5 units in 1990). However, the alkalinity of Duckpuddle Pond remains sufficient to resist fluctuations in pH, induced by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor revealed the upper mixed layer of water extended to about 4.5 meters during the 1993 season, typical of a northern temperate lake. Dissolved oxygen data, collected by the volunteer monitor, indicate the deeper waters become anoxic following the development of thermal stratification (see figures 34 and 35). By July 11, the oxygen concentration was reduced below 3 parts per million (the minimum concentration required for the successful growth and reproduction of most warmwater fish) at about 4 meters. Low hypolimnetic oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic vegetation) and external (i.e. leaf litter from watershed runoff) sources.

7) For all measurements considered and averaged for the season, Duckpuddle Pond is classified as a highly productive, eutrophic lake.

8) Water Quality data collected from the Duckpuddle Pond deep sampling station (representative of the average pond conditions) between 1988 and 1993 reveal variable chlorophyll *a* and Secchi Disk levels over the aforementioned time span (see figures 31-33 and Appendix A). While variable, the data remains indicative of a highly productive lake and the extremely high phosphorus concentrations in 1993 are indicative of increased nutrient loading. Both internal nutrient loading (nutrients released from the sediments) and external (i.e. high phosphates from the Glendon Brook) are contributing to the high productivity levels observed. High nutrient concentration in the Glendon Brook (documented through phosphorus sampling) suggest potential problem areas within the Duckpuddle Pond watershed. Possible phosphate sources include failing and improperly

installed septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, as well as, agricultural practices. An initial survey of various points along Tobias Pond (March 27, 1994) revealed excessive phosphorus concentrations near the outlet of Tobias Pond, the 22 East sampling station and the 10 Glendon Stream sampling station (see figure 27 for site locations and phosphorus concentrations). We recommend performing a watershed survey to locate the potential problem areas within the watershed. We can than expand the monitoring program to investigate these more localized problematic regions.

Figure 27. Location of the 1994 Duckpuddle Pond inlet sampling stations on a March 27, 1994 survey of the Glendon Stream drainage area. Note the excessive phosphorus concentrations measured at the 10 Glendon Stream, 22 East and 24 Tobias Outlet sampling stations.

DUCKPUDDLE POND
TIBUTARY (INLET) ASSESSMENT
MARCH 27, 1994

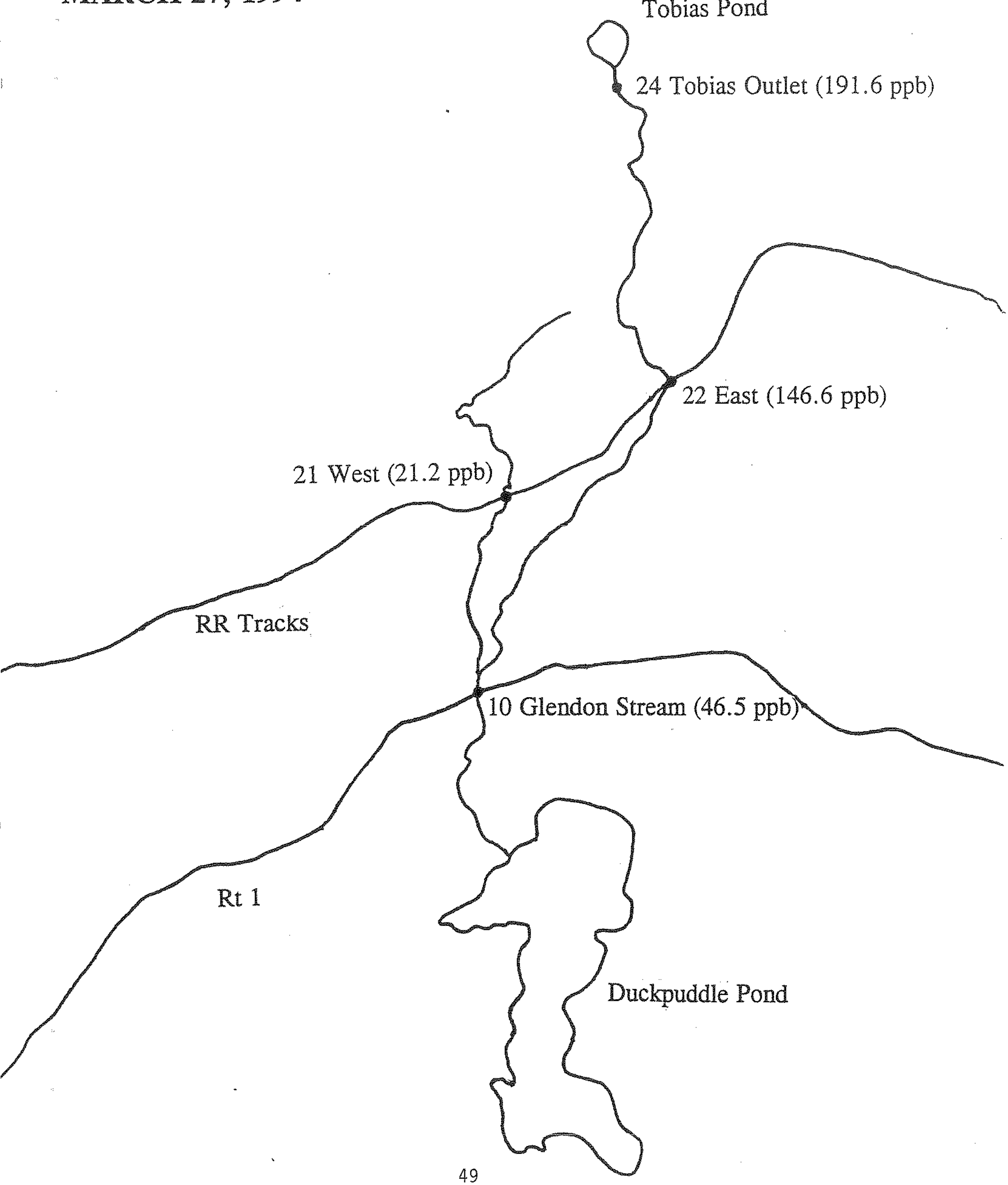
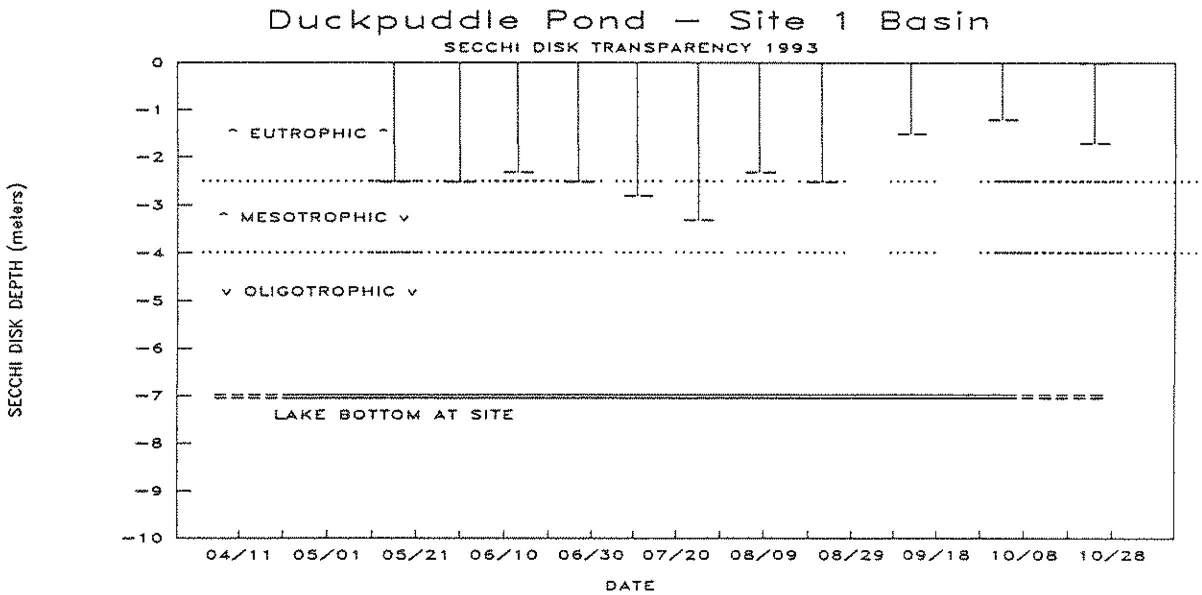
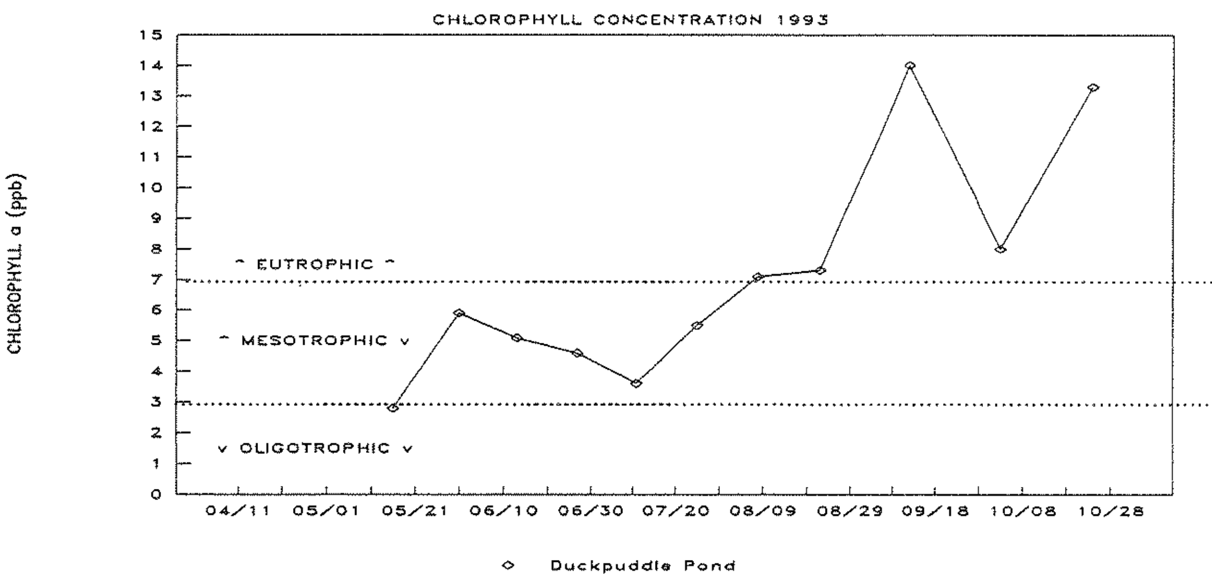


Figure 28. Duckpuddle Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) lay monitor Site 1 Basin. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum depth at the site.

Figure 29. Duckpuddle Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 30. Duckpuddle Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.


Duckpuddle Pond — Site 1 Basin
SECCHI DISK TRANSPARENCY 1993
SECCHI DISK DEPTH (meters)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
LAKE BOTTOM AT SITE
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
DATE


CHLOROPHYLL CONCENTRATION 1993
CHLOROPHYLL a (ppb)
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
Duckpuddle Pond

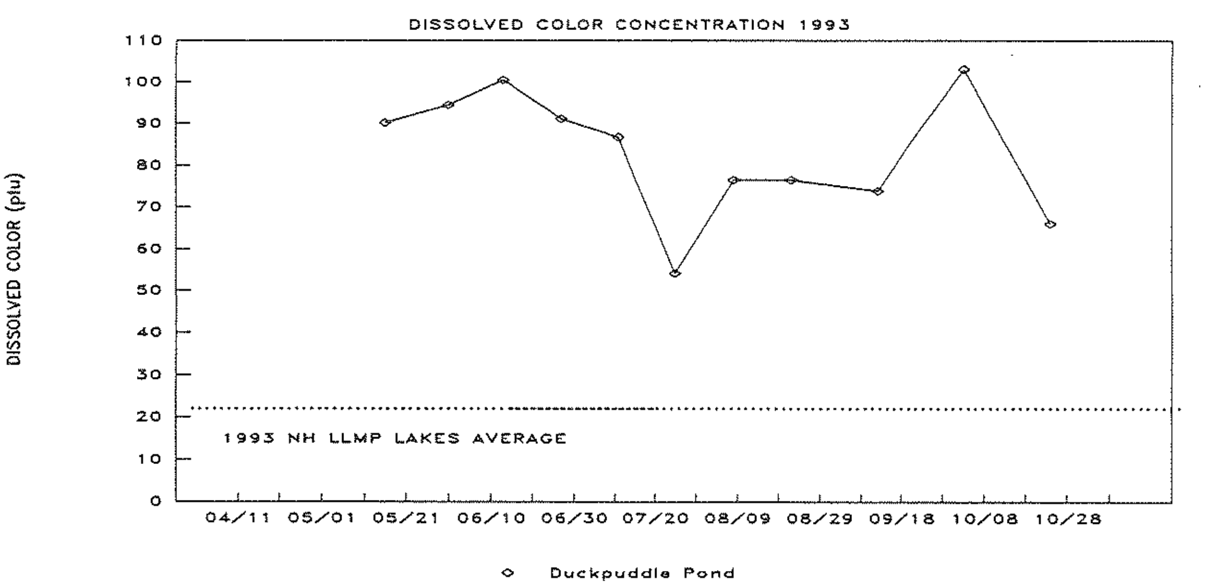
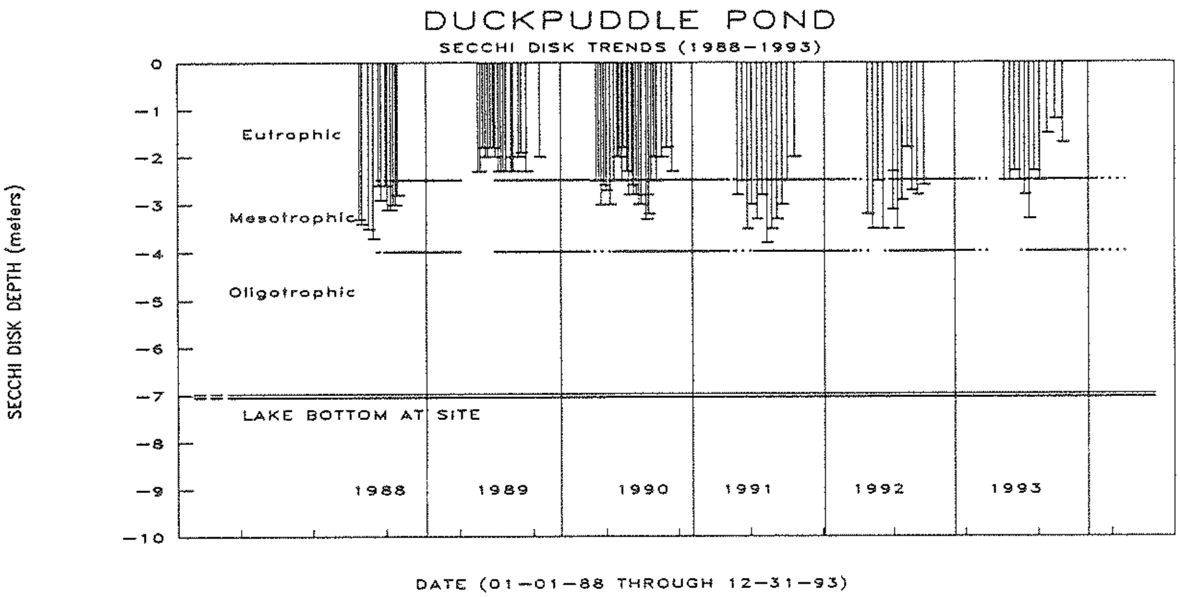

DISSOLVED COLOR CONCENTRATION 1993
DISSOLVED COLOR (ptu)
1993 NH LLMP LAKES AVERAGE
0
10
20
30
40
50
60
70
80
90
100
110
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
Duckpuddle Pond

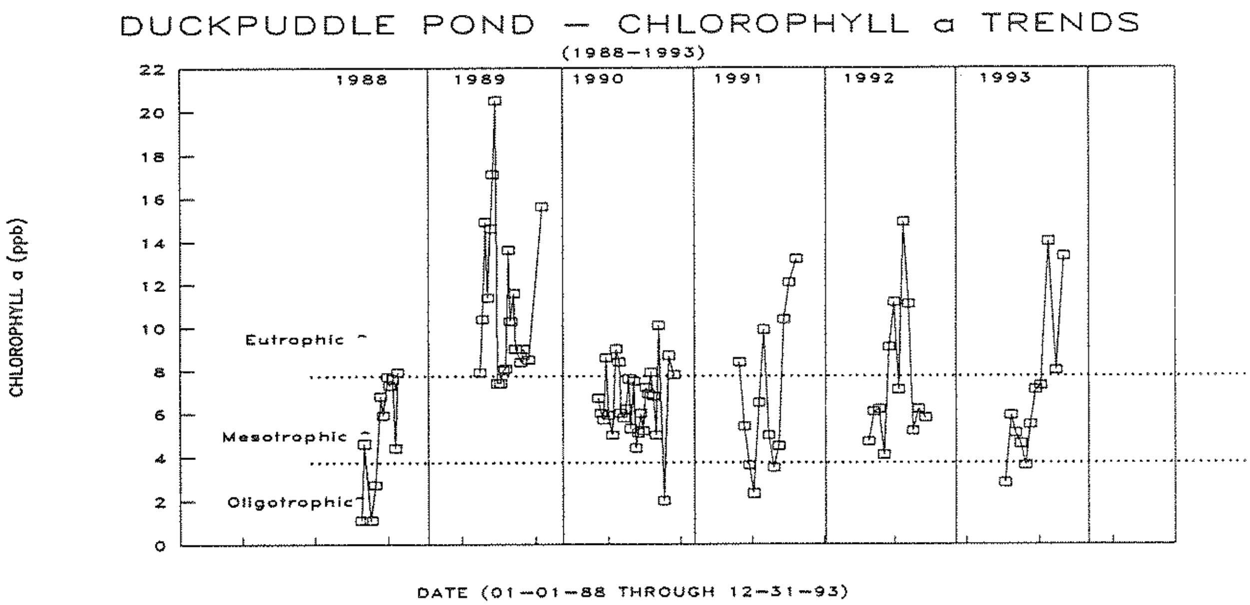
Figure 31. Duckpuddle Pond, 1988-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Basin. The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling. The maximum site depth is also included and denoted by the double solid horizontal line.

Figure 32. Duckpuddle Pond, 1988-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

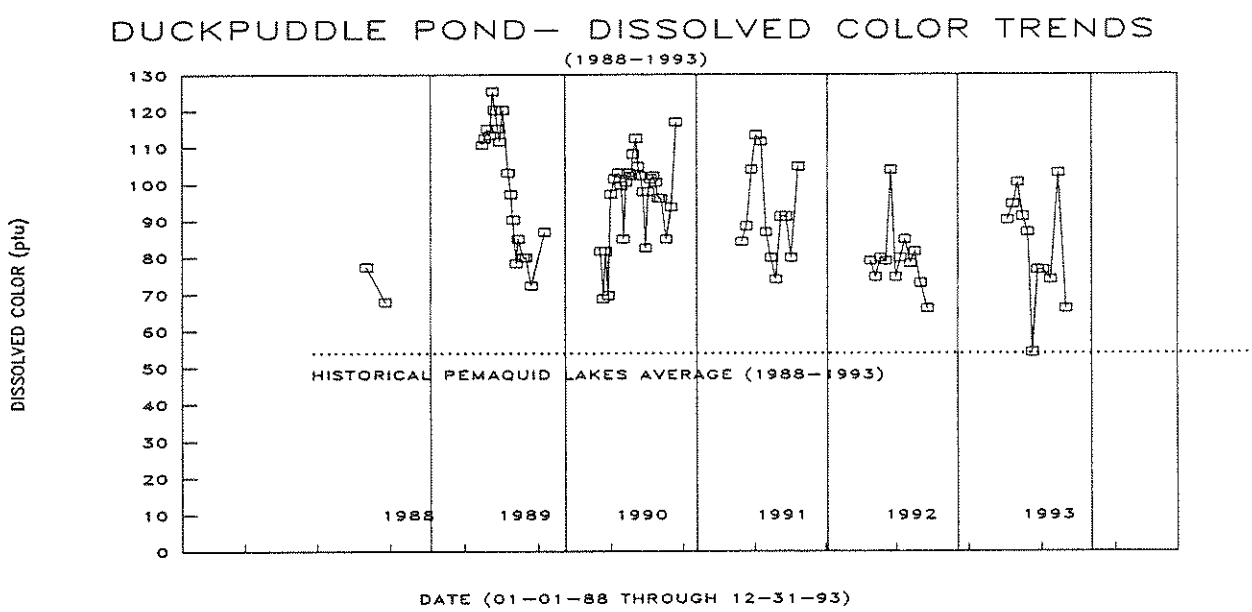
Figure 33. Duckpuddle Pond, 1988-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.



DUCKPUDDLE POND
SECCHI DISK TRENDS (1988–1993)
SECCHI DISK DEPTH (meters)
Eutrophic
Mesotrophic
Oligotrophic
LAKE BOTTOM AT SITE
1988
1989
1990
1991
1992
1993
DATE (01–01–88 THROUGH 12–31–93)



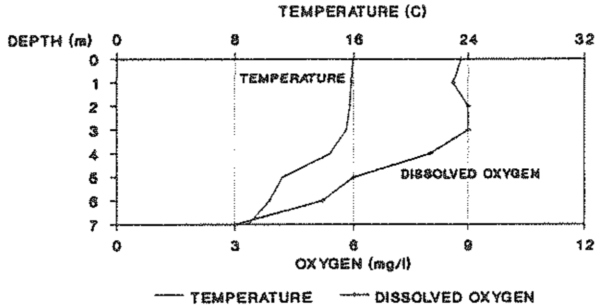
DUCKPUDDLE POND – CHLOROPHYLL a TRENDS
(1988–1993)
CHLOROPHYLL a (ppb)
1988
1989
1990
1991
1992
1993
Eutrophic
Mesotrophic
Oligotrophic
DATE (01–01–88 THROUGH 12–31–93)



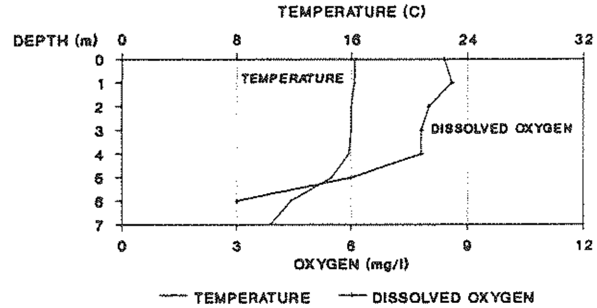
DUCKPUDDLE POND– DISSOLVED COLOR TRENDS
(1988–1993)
DISSOLVED COLOR (plu)
HISTORICAL PEMAQUID LAKES AVERAGE (1988–1993)
1988
1989
1990
1991
1992
1993
DATE (01–01–88 THROUGH 12–31–93)

Figure 34. Profiles of temperature and dissolved oxygen taken in Duckpuddle Pond, Site 1 Basin. The collection date and units of measurement are as indicated on the respective graphs. Dissolved oxygen and temperature were measured at one meter intervals.

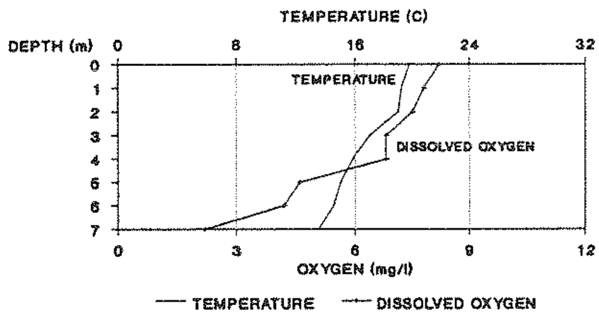
TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
MAY 16, 1993



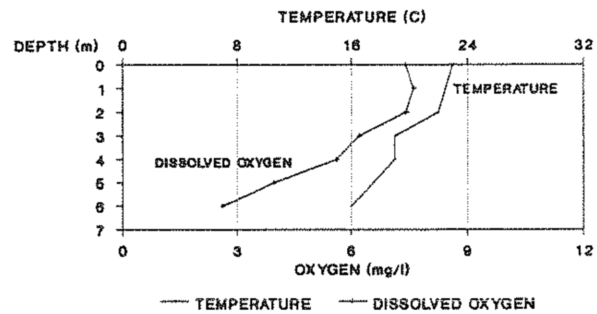
TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
MAY 31, 1993



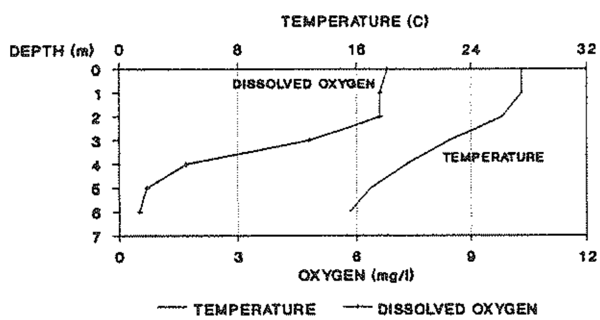
TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
JUNE 13, 1993



TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
JUNE 27, 1993

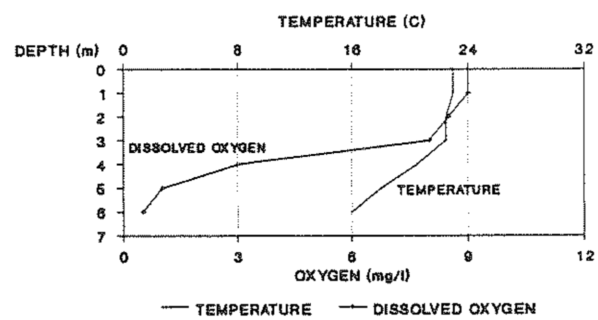


TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
JULY 11, 1993



NOTE: LOW OXYGEN CONCENTRATIONS IN THE DEEPER WATERS (BELOW 3 mg/l)

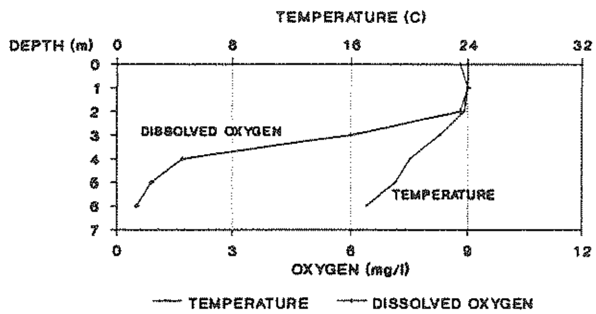
TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
JULY 25, 1993



NOTE: LOW OXYGEN CONCENTRATIONS IN THE DEEPER WATERS (BELOW 3 mg/l)

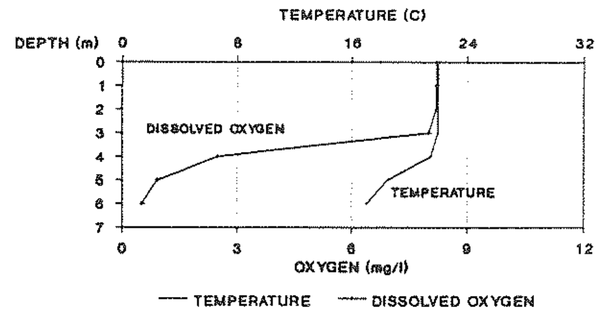
Figure 35. Profiles of temperature and dissolved oxygen taken in Duckpuddle Pond, Site 1 Basin. The collection date and units of measurement are as indicated on the respective graphs. Dissolved oxygen and temperature were measured at one meter intervals.

TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
AUGUST 8, 1993



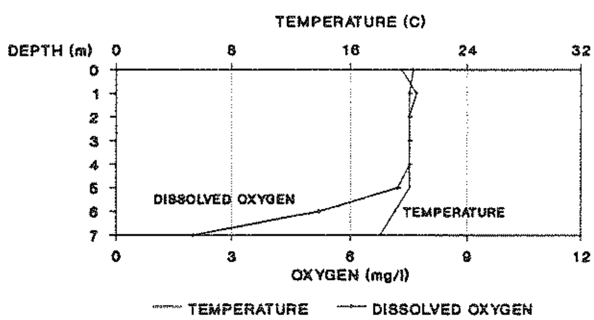
NOTE: LOW OXYGEN CONCENTRATIONS IN THE DEEPER WATERS (BELOW 3 mg/l)

TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
AUGUST 22, 1993

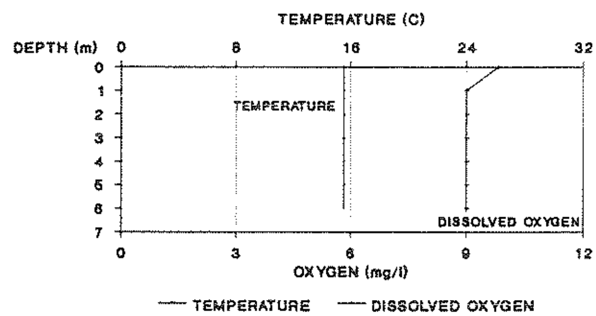


NOTE: LOW OXYGEN CONCENTRATIONS IN THE DEEPER WATERS (BELOW 3 mg/l)

TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
SEPTEMBER 12, 1993



TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
OCTOBER 3, 1993



TEMPERATURE - OXYGEN PROFILE
DUCKPUDDLE POND - SITE 1 BASIN
OCTOBER 24, 1993

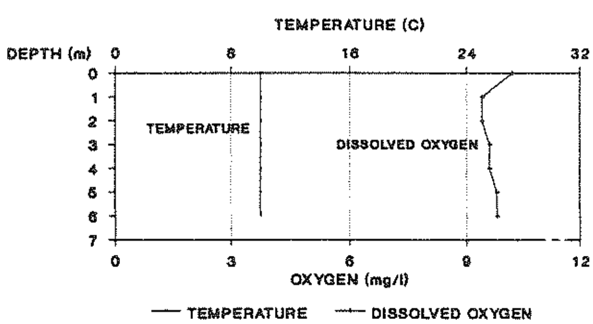


Table 4. McCurdy Pond -- trophic indicators, 1993

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY

Average transparency:	5.7	(1993:	12	values;	5.0 -	6.5 range)
Average chlorophyll:	2.1	(1993:	12	values;	1.5 -	2.7 range)
Average lake phos.:	5.3	(1993:	2	values;	2.2 -	8.4 range)
Average color, 440:	24.3	(1993:	12	values;	18.0 -	42.1 range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Basin	05/08/1993	5.8	2.7	2.2	---	---	42.1
1 Basin	05/24/1993	6.3	1.9	---	---	---	25.8
1 Basin	06/06/1993	6.0	2.3	---	---	---	24.9
1 Basin	06/20/1993	5.1	1.5	---	---	---	26.6
1 Basin	07/02/1993	5.3	1.6	---	---	---	24.9
1 Basin	07/17/1993	5.5	1.9	---	---	---	23.2
1 Basin	07/31/1993	5.0	2.7	---	---	---	21.5
1 Basin	08/14/1993	5.5	2.0	---	---	---	25.8
1 Basin	08/28/1993	5.8	2.3	---	---	---	20.6
1 Basin	09/11/1993	6.5	2.1	---	---	---	19.8
1 Basin	09/25/1993	5.5	1.7	---	---	---	18.0
1 Basin	10/08/1993	5.7	2.3	8.4	---	---	18.0

<< End of 1993 listing, 12 records >>

MCCURDY POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of McCurdy Pond was undertaken by the volunteer monitor, Albert Rogers, from May 8 through October 8, 1993 (see table 4 and figures 36-38). The following data summarize the 1993 conditions of McCurdy Pond, and when applicable, incorporate historical data into the interpretation. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) Water transparency at McCurdy Pond was representative of a moderately productive lake according to the criteria employed by the **Maine Department of Environmental Protection (DEP)**. The seasonal average water transparency of 5.7 meters (17.6 feet) is slightly less than the 1992 average Secchi Disk transparency (6.1 meters) but remains within the historical levels recorded for McCurdy Pond.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) for the surface waters of McCurdy Pond were low to moderate in 1993. The seasonal chlorophyll *a* concentration averaged 2.1 milligrams per cubic meter (2.1 mg m^{-3} equivalent to 2.1 parts chlorophyll *a* per billion parts water) at Site 1 Basin which falls within the **Maine DEP** criteria for a borderline unproductive to moderately productive lake.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for McCurdy Pond were low to moderate in 1993, 24.3 platinate color units (ptu). McCurdy Pond is the least colored of the participating **Pemaquid Watershed Association** pond's, translating into higher water clarities in the former pond.

4) Total phosphorus samples (generally considered the limiting nutrient for microscopic plant growth in freshwater systems), collected from the deep, in-lake,

sampling station early (May 8), 2.2 ppb, and late (October 8), 8.4 ppb, in the season remained within the ranges typical of a borderline unproductive/moderately productive lake (see table 4 for 1993 total phosphorus results). The 1993 phosphorus concentrations are within historical phosphorus concentrations recorded by the **NH LLMP** and the **Maine DEP**. Elevated phosphorus concentrations documented in October might be the result of internal nutrient loading (due to the mixing of the deep water layer with the surface layer). Data collected by the **Maine DEP** indicated hypolimnetic (bottom water) phosphorus concentrations reached 40 ppb in 1985 while the **NH LLMP** noted hypolimnetic phosphorus accumulation (14.1 ppb) in 1991.

5) The pond's alkalinity (buffering capacity against acid precipitation), recorded by the **Maine DEP** (1985) is low, 3.7 units, but sufficient to resist fluctuations in pH, induced by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor revealed the upper mixed layer of water extended to about 6 meters during the 1993 season, typical of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP**, indicate oxygen concentrations are reduced in the bottom (hypolimnetic) waters of McCurdy Pond during thermal stratification. Low hypolimnetic oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic vegetation) and external (i.e. leaf litter from watershed runoff) sources.

7) For all measurements considered and averaged for the season, McCurdy Pond is classified as a relatively clear, borderline unproductive/moderately productive, oligotrophic/mesotrophic lake.

8) Water Quality data collected from the McCurdy Pond deep sampling station (representative of the average pond conditions) between 1988 and 1993 indicate a trend of

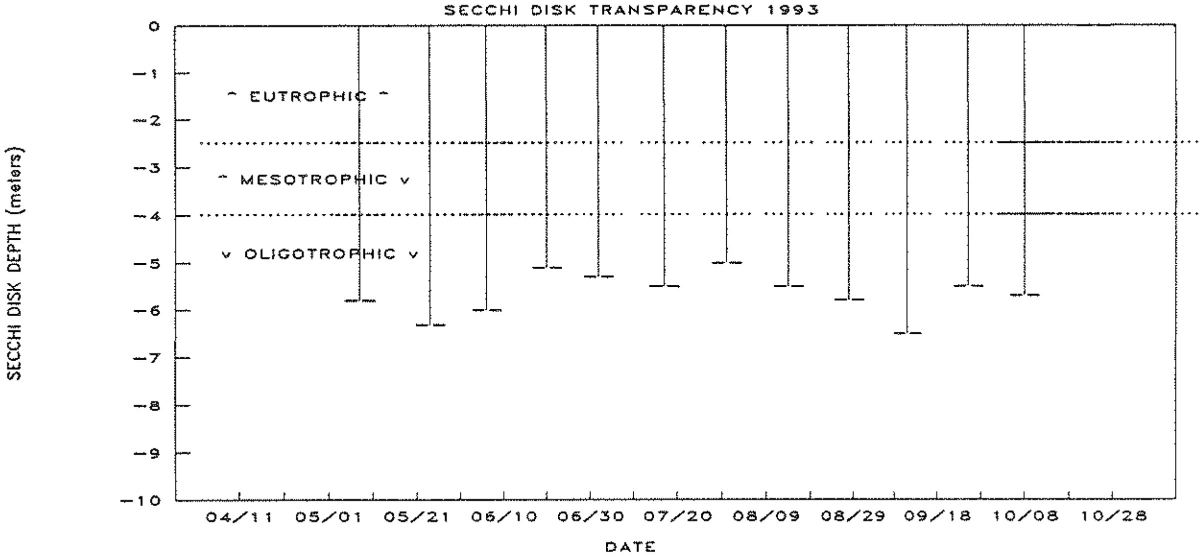
decreasing surface water (epilimnetic) chlorophyll *a* concentrations while the Secchi Disk transparencies revealed a more variable pattern over the aforementioned time span (see figures 39-41 and Appendix A). As the dissolved color concentration of McCurdy Pond remained relatively low between 1988 and 1993, allowing light penetration to the deeper waters, the variable Secchi Disk readings from year to year might be a response to mid-lake algal populations which are not evident from surface sampling alone. Based on the collected water quality parameters for McCurdy Pond, the pond continues to exhibit high water quality which might have improved slightly over the past six years of sampling. While data collected from the deep sampling station, Site 1 Center, indicates continued high water quality, more localized problems (i.e. failing and improperly installed septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) might be overlooked in the shallows and in more embayed areas of McCurdy Pond. If such problem areas are a concern, we recommend performing a shoreline survey of the lake and/or a watershed survey to locate the potential problem areas within the watershed. We can than expand the monitoring program to investigate these more localized regions if the need exists.

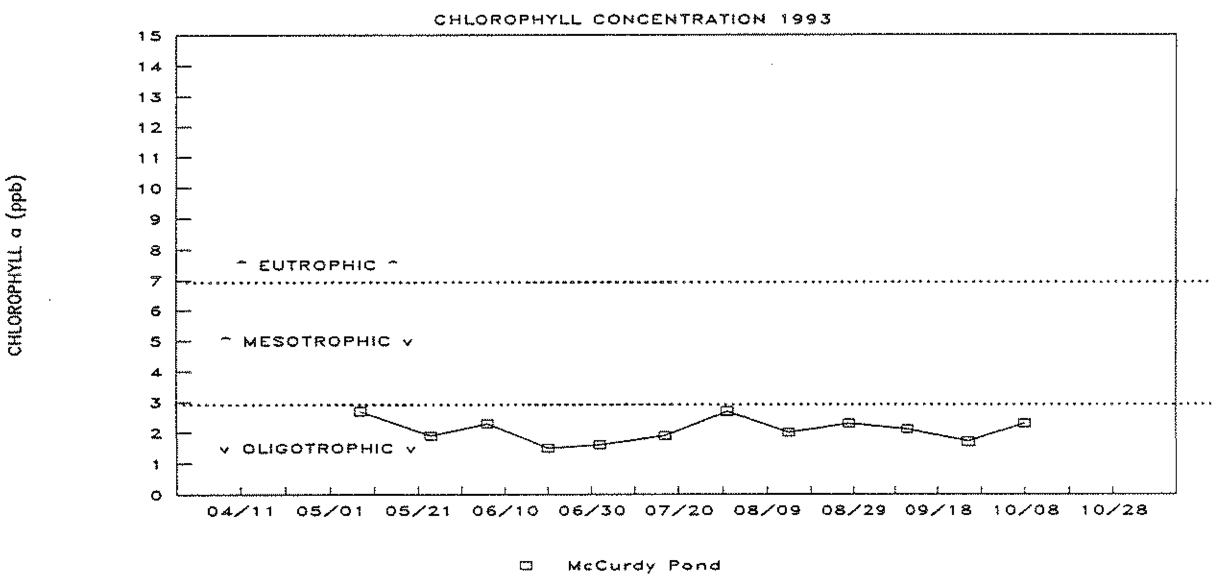
Figure 36. McCurdy Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Basin. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid line represents the maximum depth at the site.

Figure 37. McCurdy Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 38. McCurdy Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

McCurdy Pond — Site 1 Basin





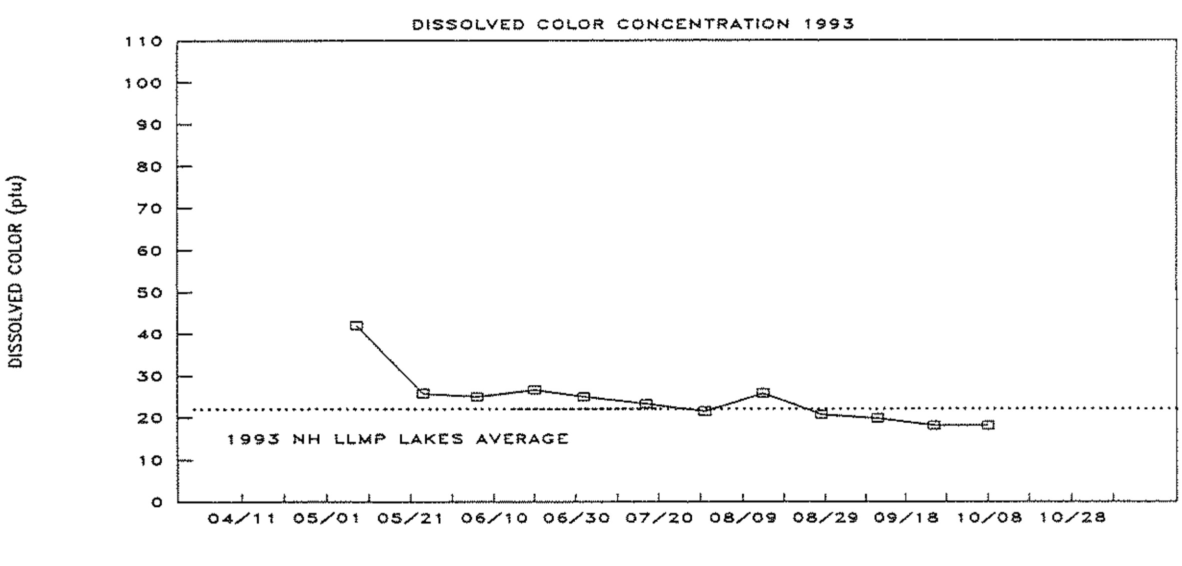
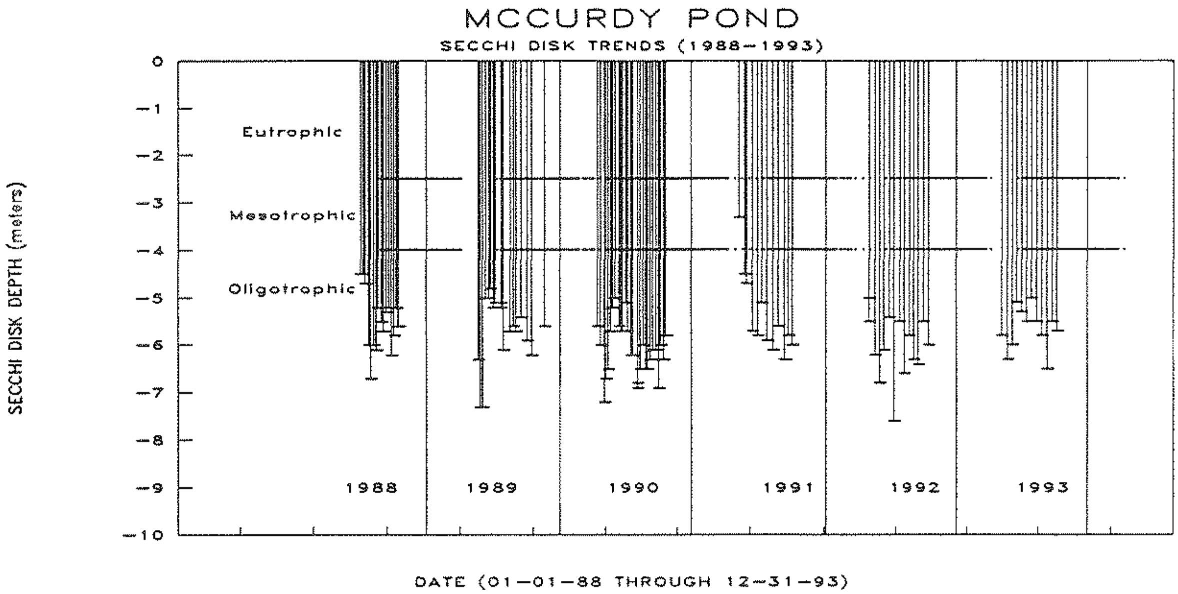
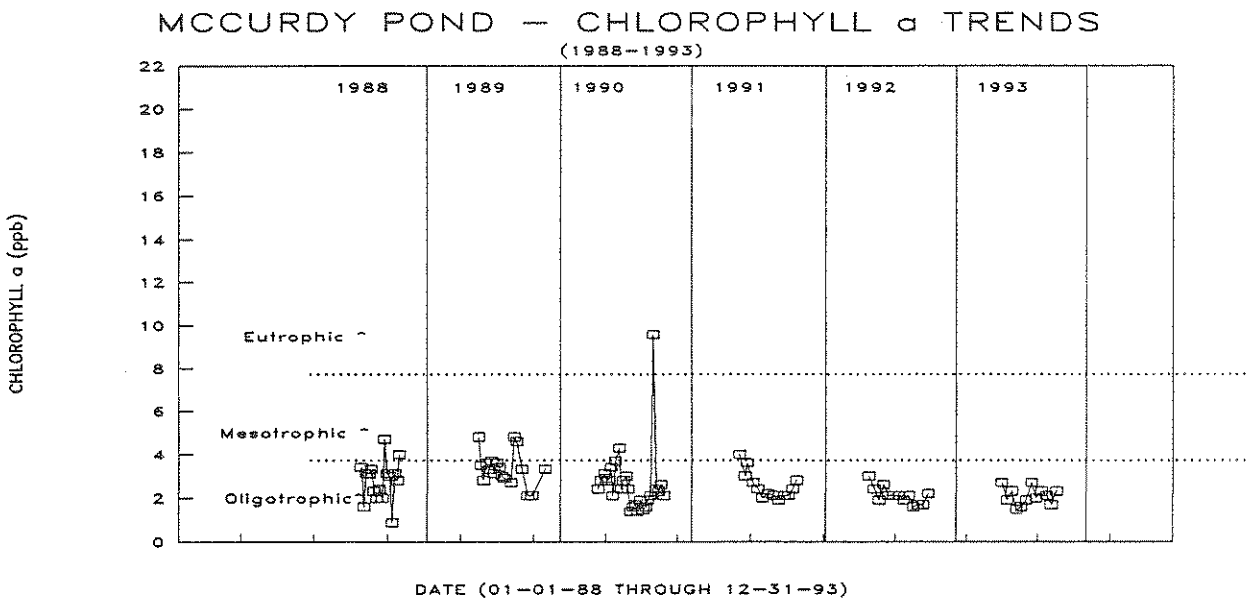


Figure 39. McCurdy Pond, 1988-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Basin. The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 40. McCurdy Pond, 1988-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 41. McCurdy Pond, 1988-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.


MCCURDY POND
SECCHI DISK TRENDS (1988-1993)
SECCHI DISK DEPTH (meters)
Eutrophic
Mesotrophic
Oligotrophic
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)


MCCURDY POND - CHLOROPHYLL a TRENDS
(1988-1993)
CHLOROPHYLL a (ppb)
Eutrophic
Mesotrophic
Oligotrophic
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)

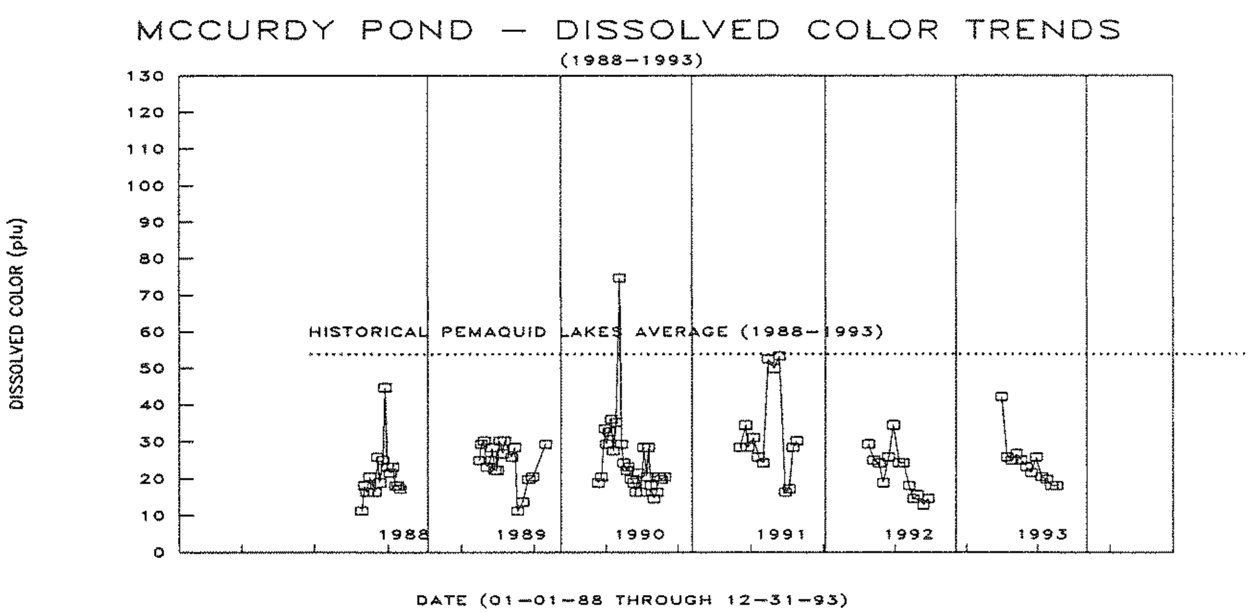

MCCURDY POND - DISSOLVED COLOR TRENDS
(1988-1993)
DISSOLVED COLOR (plu)
HISTORICAL PEMAQUID LAKES AVERAGE (1988-1993)
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)

Table 5. Paradise Pond -- trophic indicators, 1993

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY							
Average transparency:	3.5	(1993:	5	values;	3.1 -	3.9	range)
Average chlorophyll:	4.0	(1993:	12	values;	2.5 -	9.3	range)
Average lake phos.:	9.4	(1993:	2	values;	8.6 -	10.1	range)
Average color, 440:	70.3	(1993:	12	values;	50.7 -	96.2	range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
2 North	05/09/1993	3.8	3.3	8.6	---	---	96.2
2 North	05/23/1993	3.9	4.7	---	---	---	83.3
2 North	06/08/1993	3.1	4.1	---	---	---	79.0
2 North	06/20/1993	3.1	5.1	---	---	---	79.0
2 North	07/05/1993	3.5	9.3	---	---	---	76.5
2 North	07/18/1993	bottom	4.3	---	---	---	72.2
2 North	08/01/1993	bottom	2.8	---	---	---	64.4
2 North	08/14/1993	bottom	2.5	---	---	---	72.2
2 North	08/29/1993	bottom	3.1	---	---	---	58.4
2 North	09/12/1993	bottom	2.8	---	---	---	56.7
2 North	09/24/1993	bottom	2.7	---	---	---	55.0
2 North	10/10/1993	bottom	3.3	10.1	---	---	50.7

<< End of 1993 listing, 12 records >>

PARADISE POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of Paradise Pond was undertaken by the volunteer monitor, Steve O'Bryan, from May 9 through October 10, 1993 (see table 5 and figures 42-44). The following data summarize the 1993 conditions of Paradise Pond, and when applicable, incorporate historical data into the interpretation. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements". Note: historical water quality measurements were taken at the 1 Reed Island sampling station (1988-1990) while latter samples (1991-1993) were collected about one-half mile north of the former sampling station at a site denoted 2 North.

1) Water transparency at Paradise Pond ranged from 3.1 to about 3.9 meters (at which time the Secchi Disk rested on the lakebottom). Due to the shallowness of the pond, it is difficult to utilize the Secchi Disk depth as a trophic (productivity) indicator, since the Secchi Disk often reached the lakebottom before disappearing from view. However, reductions in the Secchi Disk depth can indicate perturbations in water quality during the sampling season. The lowest Secchi Disk readings of 3.1 meters (June 8 and June 20) corresponded to high levels of pine pollen in the water column. Other participating **LLMP** lakes have noted similar phenomenon when pine pollen is at its peak. While events such as these reduce water clarity measurements, they are naturally occurring short term perturbations to water clarity, and not the result of deleterious land use practices within the watershed. (note: all inputs of organic matter will naturally lead to the "greening" of ones lake over geological time: thousands of years. However, the current concern is that land use changes within the watershed will augment this process: tens of years).

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) for the surface waters of Paradise Pond were moderate in 1993. The seasonal chlorophyll *a* concentration averaged 4.0 milligrams per cubic meter (4.0 mg m^{-3} equivalent to 4.0 parts chlorophyll *a* per billion parts water) at Site 2 North which falls within the **Maine DEP** criteria for a moderately productive lake.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for Paradise Pond were high in 1993, 70.3 platinate color units (ptu). Paradise Pond, like Duckpuddle Pond, is surrounded by wetland areas which contribute to the high dissolved color levels. The highest color levels occurred early in the season (May) and gradually decreased as the season progressed.

4) Total phosphorus samples (generally considered the limiting nutrient for microscopic plant growth in freshwater systems), collected from the deep, in-lake sampling station were moderate when sampled early in the season (May 9), 8.6 ppb, and again late in the season (October 10), 10.1 ppb (see table 5 for 1993 total phosphorus results). The 1993 phosphorus concentrations are within the range of historical phosphorus concentrations recorded by the **NH LLMP** and the **Maine DEP** and are typical of a moderately productive lake.

5) The pond's alkalinity (buffering capacity against acid precipitation), recorded by the **Maine DEP** (1990) is moderate, 5.5 units, and sufficient to resist fluctuations in pH, induced by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor revealed Paradise Pond remained mixed throughout the summer sampling season, typical of shallow water bodies. With the lack of temperature stratification, the pond remains well oxygenated. However, during periods of inclement weather, there is a greater chance of resuspending matter

accumulated on the lakebottom of Paradise Pond than would occur in a deeper, stratified lake or pond (i.e. Biscay Pond and McCurdy Pond). The resuspension of particulate matter can diminish water clarity and can mobilize nutrients, which adhere to the sediment and detrital (decaying organic matter) particles, and thus stimulate algal growth.

7) For all measurements considered and averaged for the season, Paradise Pond is classified as a moderately productive, mesotrophic lake.

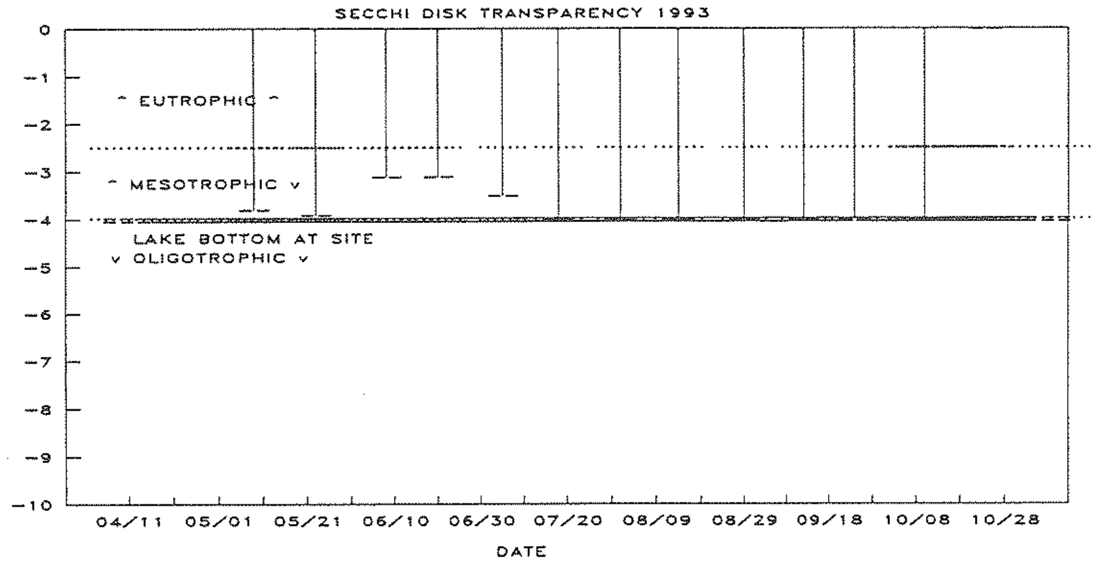
8) Water Quality data collected from the Paradise Pond deep sampling station (representative of the average pond conditions) between 1988 and 1993 indicate variable yearly chlorophyll *a* and Secchi Disk levels over the aforementioned time span (see figures 45-47 and Appendix A). At this time, no definitive trend is discernable for Paradise Pond. One must also consider the variation in site location as a possible source of variability, as the site shifted from 1 Reed Island (1988 to 1990) to a more northern site, Site 2 North (1991 to 1993). While data collected from the deep sampling stations, Sites 1 Reed Island and 2 North, are not currently indicative of declining water quality, more localized problems (i.e. failing and improperly installed septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) might be overlooked in the shallows and in more embayed areas of Paradise Pond. If such problem areas are a concern, we recommend performing a shoreline survey of the lake and/or a watershed survey to locate the potential problem areas within the watershed. We can than expand the monitoring program to investigate these more localized regions if the need exists. We also suggest the collection of Secchi Disk readings at the 1 Reed Island sampling station (as a reference point) in addition to the Secchi Disk readings collected at the 2 North sampling station. This will help discern whether or not increased development at the northern sampling station is impacting the water quality of Paradise Pond.

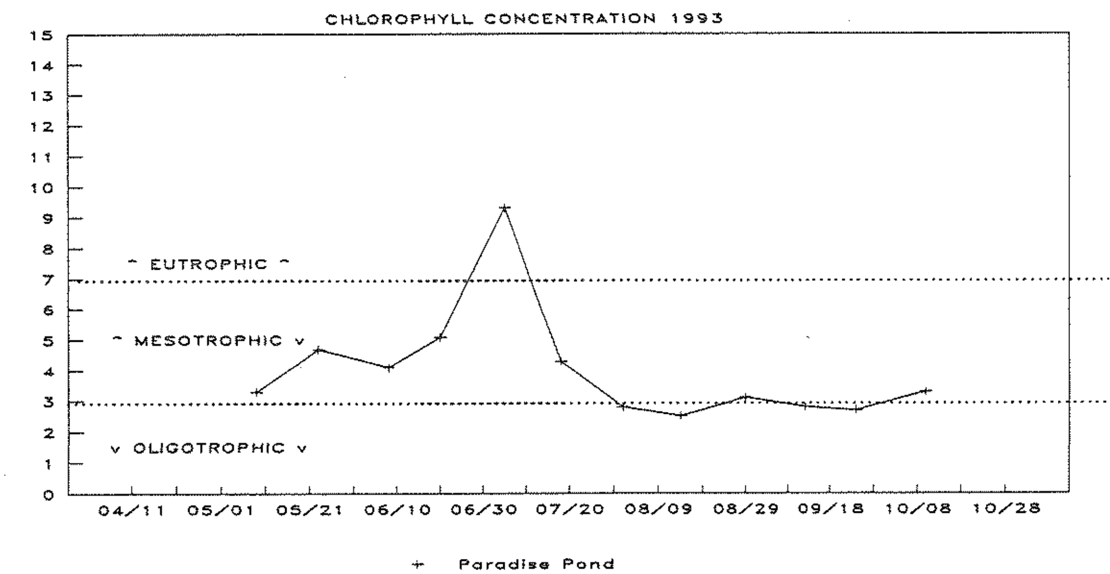
Figure 42. Paradise Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 2 North. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum depth of the site.

Figure 43. Paradise Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 2 North. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 44. Paradise Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 2 North. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

Paradise Pond — Site 2 North





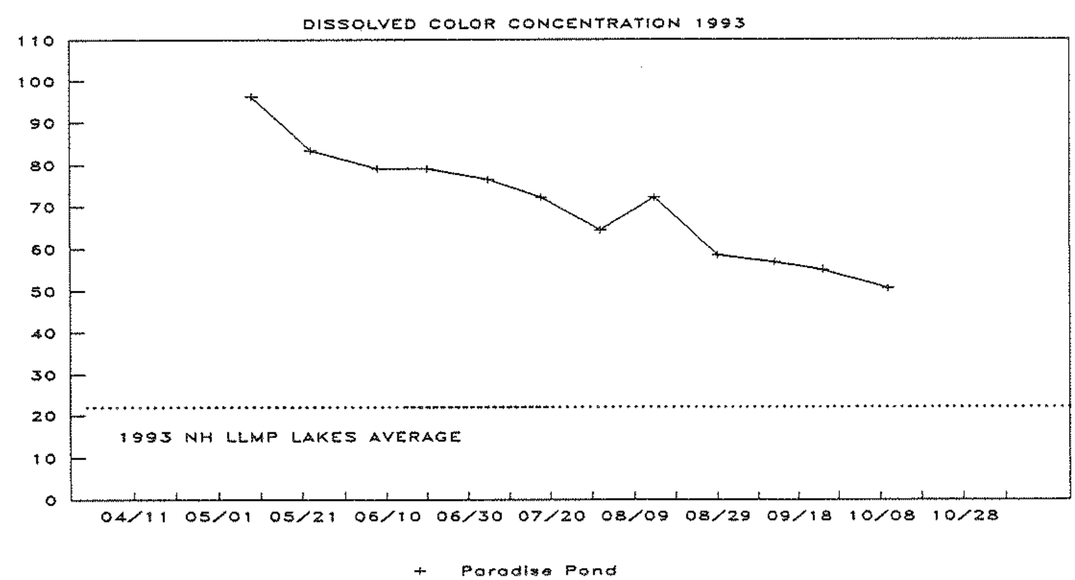
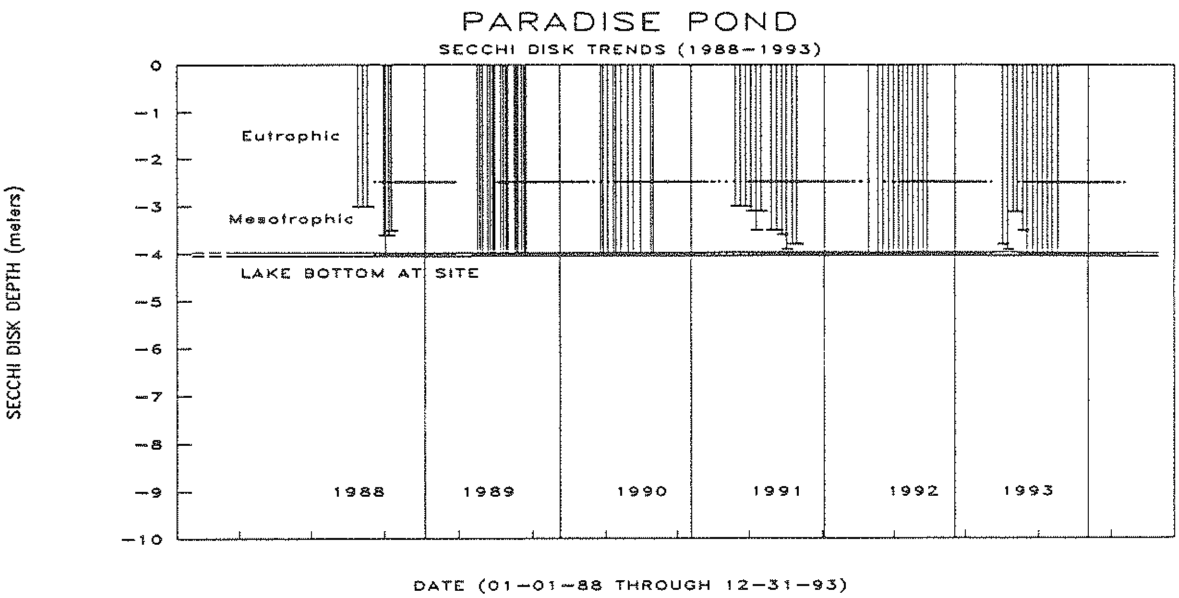
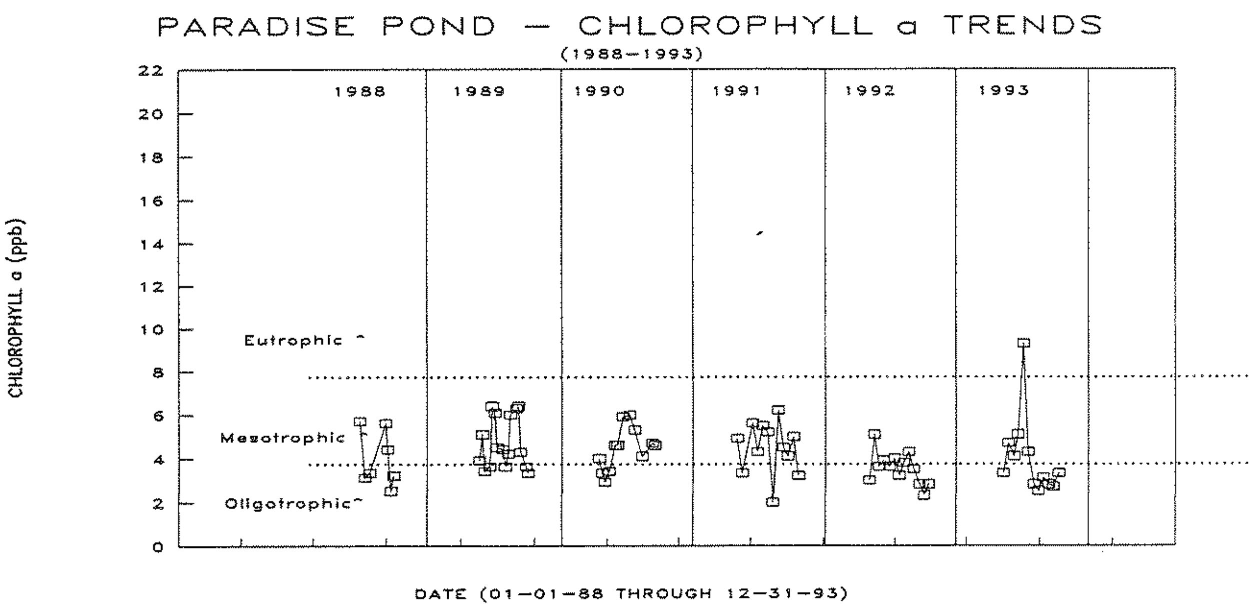


Figure 45. Paradise Pond, 1988-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Reed Island (1988-1990) and Site 2 North (1991-1993). The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling. The maximum site depth is also included and denoted by the double solid horizontal line.

Figure 46. Paradise Pond, 1988-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Reed Island (1988-1990) and Site 2 North (1991-1993). Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 47. Paradise Pond, 1988-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Reed Island (1988-1990) and Site 2 North (1991-1993). Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.


PARADISE POND
SECCHI DISK TRENDS (1988–1993)
SECCHI DISK DEPTH (meters)
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
Eutrophic
Mesotrophic
LAKE BOTTOM AT SITE
1988
1989
1990
1991
1992
1993
DATE (01–01–88 THROUGH 12–31–93)


PARADISE POND — CHLOROPHYLL a TRENDS
(1988–1993)
CHLOROPHYLL a (ppb)
22
20
18
16
14
12
10
8
6
4
2
0
1988
1989
1990
1991
1992
1993
Eutrophic
Mesotrophic
Oligotrophic
DATE (01–01–88 THROUGH 12–31–93)

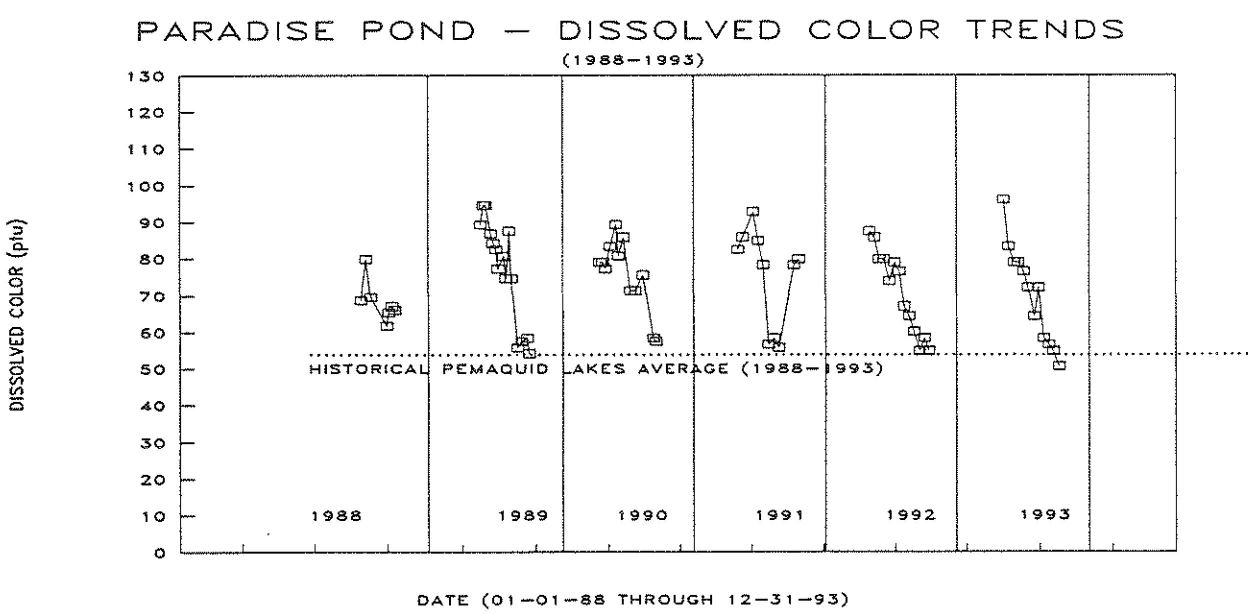

PARADISE POND — DISSOLVED COLOR TRENDS
(1988–1993)
DISSOLVED COLOR (plu)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
HISTORICAL PEMAQUID LAKES AVERAGE (1988–1993)
1988
1989
1990
1991
1992
1993
DATE (01–01–88 THROUGH 12–31–93)

Table 6. Pemaquid Pond -- trophic indicators, 1993

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

1993 SUMMARY

Average transparency:	4.7	(1993:	9	values;	3.5 - 6.0 range)
Average chlorophyll:	2.5	(1993:	9	values;	1.9 - 3.6 range)
Average lake phos.:	7.4	(1993:	4	values;	3.1 - 12.1 range)
Average color, 440:	44.2	(1993:	9	values;	33.5 - 73.0 range)
Average trib phos.:	3.1	(1993:	1	values;	3.1 - 3.1 range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units
1 Deep	05/08/1993	3.8	2.8	8.2	---	---	61.0
1 Deep	06/18/1993	3.5	1.9	---	---	---	73.0
1 Deep	07/02/1993	5.5	2.7	---	---	---	35.2
1 Deep	07/19/1993	4.5	3.6	---	---	---	40.4
1 Deep	08/01/1993	4.5	2.3	---	---	---	43.8
1 Deep	08/16/1993	4.5	2.4	---	---	---	36.9
1 Deep	09/15/1993	5.5	1.9	---	---	---	38.7
1 Deep	09/23/1993	4.5	2.3	---	---	---	35.2
1 Deep	10/10/1993	6.0	2.9	12.1	---	---	33.5
20 Outlet	03/27/1993	---	---	3.1	---	---	---
20 Outlet	04/24/1993	---	---	6.0	---	---	---

<< End of 1993 listing, 11 records >>

PEMAQUID POND

1993 NON-TECHNICAL SUMMARY

Bi-Weekly sampling of Pemaquid Pond was undertaken by the volunteer monitor, David McLeod, from May 8 through October 10, 1993 (see table 6 and figures 48-50). The following data summarize the 1993 conditions of Pemaquid Pond, and when applicable, incorporate historical data into the interpretation. A more detailed discussion of the sampled parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) Water transparency at Pemaquid Pond was representative of a moderately productive lake according to the criteria employed by the **Maine Department of Environmental Protection (DEP)**. The seasonal average water transparency of 4.7 meters (15.3 feet) is less than the 1992 average Secchi Disk transparency (5.9 meters) and matched the seasonal record transparency low. The lowest water clarity measurements were taken in May and June when the dissolved color concentrations were at their peak levels.

2) Chlorophyll *a* concentrations (a measure of microscopic plant abundance) for the surface waters of Pemaquid Pond were moderate in 1993. The seasonal chlorophyll *a* concentration averaged 2.5 milligrams per cubic meter (2.5 mg m^{-3} equivalent to 2.5 parts chlorophyll *a* per billion parts water) at Site 1 Basin which falls within the **Maine DEP** criteria for a moderately productive lake. The 1993 seasonal average chlorophyll *a* concentration was at its lowest level since chlorophyll *a* sampling was initiated in 1988 by the **PWA** and the **NH LLMP**.

3) Dissolved lakewater color levels (a measure of naturally occurring "background" color in lakes) for Pemaquid Pond were moderate in 1993, 44.2 platinate color units (ptu).

4) Total phosphorus samples (generally considered the limiting nutrient for microscopic plant growth in freshwater systems), collected from the deep, in-lake, sampling station early (May 8), 8.2 ppb, and late (October 10), 12.1 ppb, in the season remained within the ranges typical of a moderately productive lake (see table 6 for the 1993 phosphorus concentrations). The 1993 phosphorus concentrations are within the range of historical phosphorus levels recorded by the **NH LLMP** and the **Maine DEP**.

5) The pond's alkalinity (buffering capacity against acid precipitation), recorded by the **Maine DEP** (1987 and 1991) is moderate to high, 8.0 to 10.0 units, and sufficient to resist fluctuations in pH, induced by acid loadings, at this time.

6) Temperature profiles collected by the Lay Monitor revealed the upper mixed layer of water extended to about 7.0 meters during the 1993 season, typical of a northern temperate lake. Historical oxygen data, collected by the **Maine DEP** (1981, 1984, 1987, 1988 and 1991), indicate oxygen concentrations are reduced in the bottom (hypolimnetic) waters of Pemaquid Pond during thermal stratification. Low hypolimnetic oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic vegetation) and external (i.e. leaf litter from watershed runoff) sources.

7) For all measurements considered and averaged for the season, Pemaquid Pond is classified as a moderately productive, mesotrophic lake.

8) Water Quality data collected from the Pemaquid Pond deep sampling station (representative of the average pond conditions) between 1988 and 1993 indicate a trend of increasing Secchi Disk transparency with the exception of the 1993 data (see figures 51-53 and Appendix A). The chlorophyll *a* data is more variable but remains within the range of a moderately productive lake. That is to say, the productivity of Pemaquid Pond has improved slightly from 1988 to 1992. However, the sudden decline in the 1993 Secchi

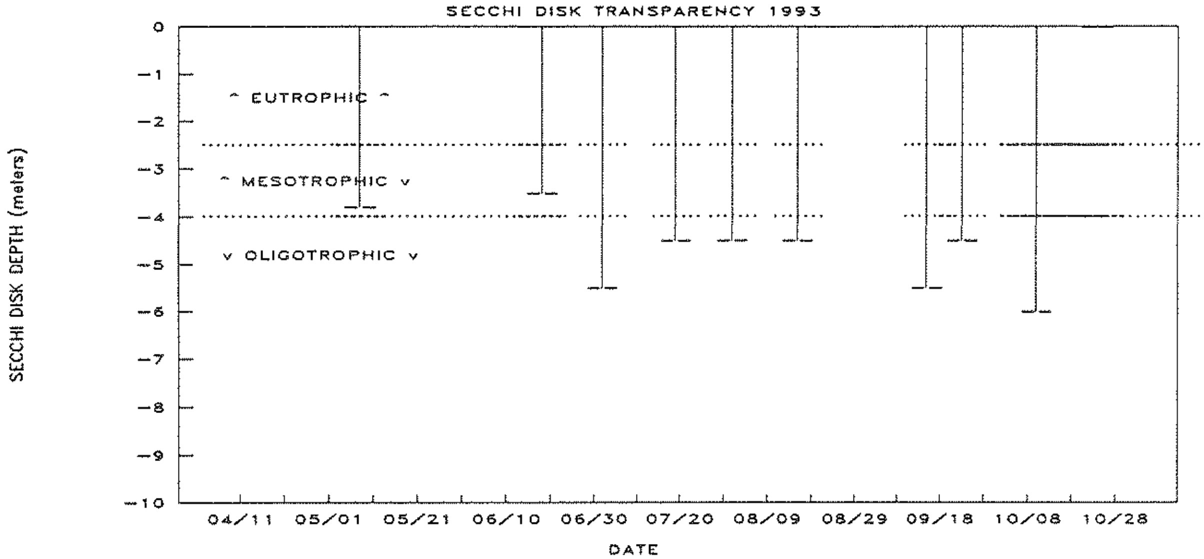
Disk readings is not consistent with the previous yearly data and should be investigated, although early season water clarity reductions can be partially explained by high dissolved color concentrations at that time. We recommend performing a shoreline survey of the lake and/or a watershed survey to locate the potential problem areas (i.e. failing and improperly installed septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) within the watershed. We can than expand the monitoring program to investigate these more localized regions if the need exists. We also suggest the initiation of lake sampling in the northern basin of Pemaquid Pond to document water quality changes in this region of the lake. As the various basins of a lake can function as individual water bodies, monitoring of this region will more completely assess the condition of Pemaquid Pond.

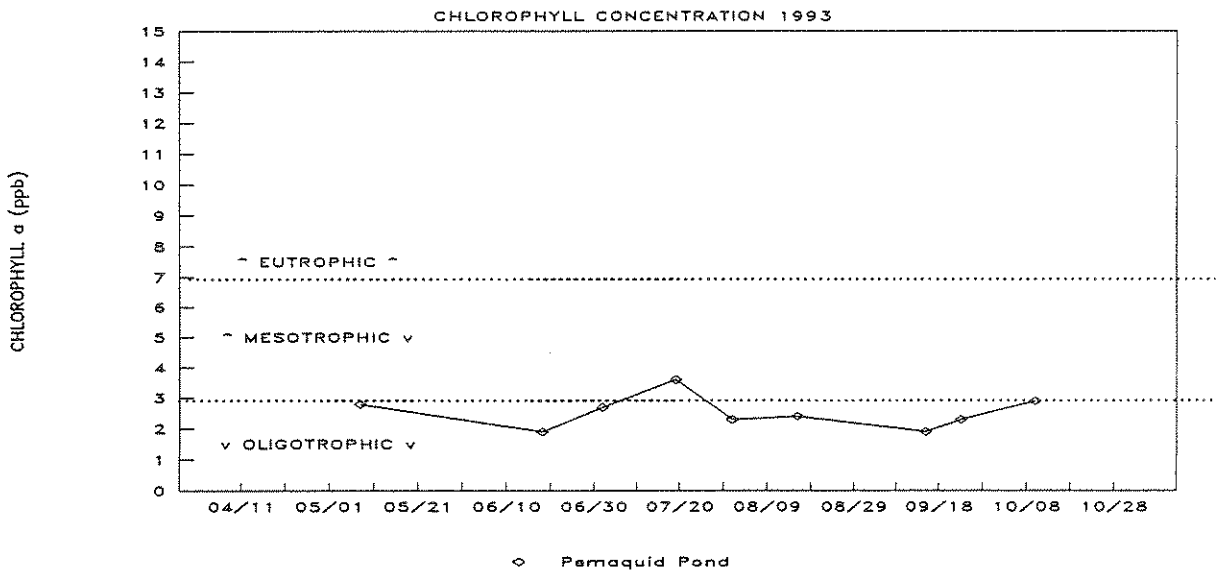
Figure 48. Pemaquid Pond, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Basin. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 49. Pemaquid Pond, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 50. Pemaquid Pond, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

Pemaquid Pond — Site 1 Deep





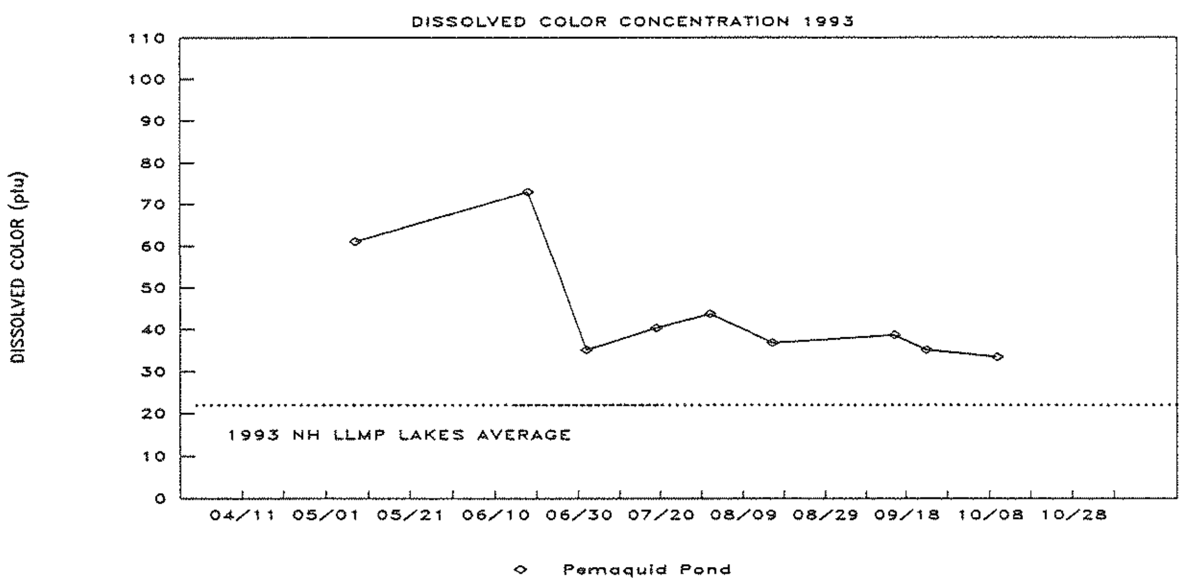
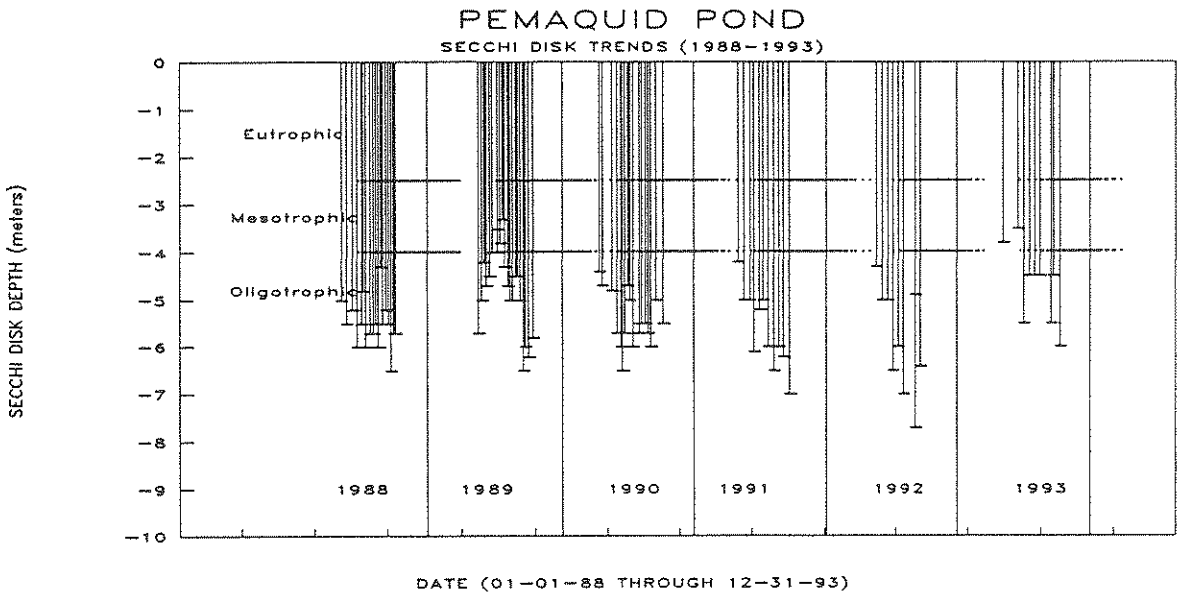
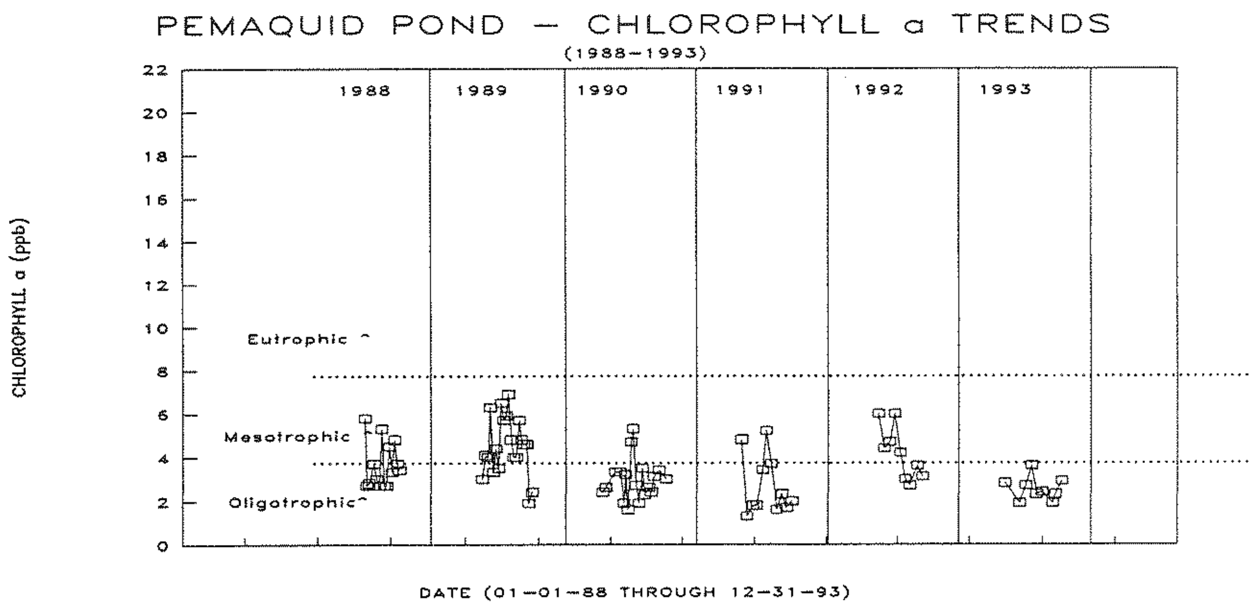


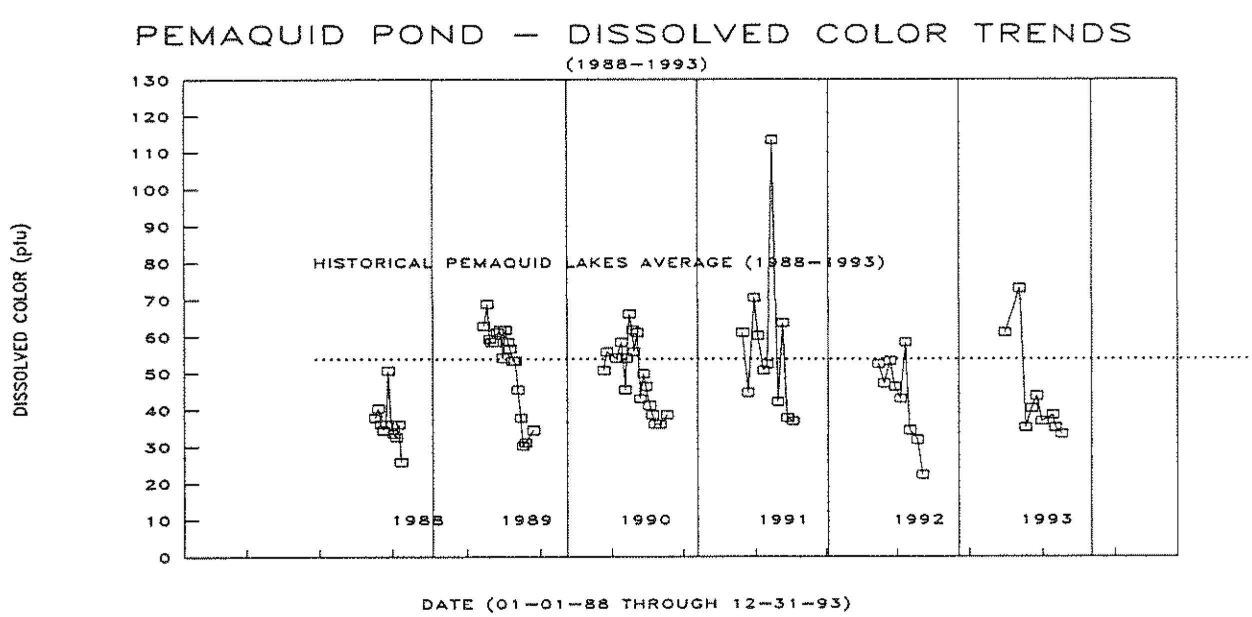
Figure 51. Pemaquid Pond, 1988-1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 Basin. The solid horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 52. Pemaquid Pond, 1988-1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 Basin. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 53. Pemaquid Pond, 1988-1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 Basin. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the historical dissolved color average for the participating Pemaquid Ponds while the solid vertical lines differentiate the years of sampling.


PEMAQUID POND
SECCHI DISK TRENDS (1988-1993)
SECCHI DISK DEPTH (meters)
Eutrophic
Mesotrophic
Oligotrophic
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)


PEMAQUID POND - CHLOROPHYLL a TRENDS
(1988-1993)
CHLOROPHYLL a (ppb)
Eutrophic
Mesotrophic
Oligotrophic
22
20
18
16
14
12
10
8
6
4
2
0
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)


PEMAQUID POND - DISSOLVED COLOR TRENDS
(1988-1993)
DISSOLVED COLOR (ptu)
HISTORICAL PEMAQUID LAKES AVERAGE (1988-1993)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1988
1989
1990
1991
1992
1993
DATE (01-01-88 THROUGH 12-31-93)

COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the **Pemaquid Watershed Association**, continue to develop its data base on lake water quality through continuation of the long term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and eventually will enable more reliable predictions of water quality trends.

2) We recommend continued phosphorus sampling both early (during spring snowmelt and the heavy spring rains) and again late in the season (when septic systems have been put through a full summer's use) to monitor nutrient loadings into the Pemaquid Watershed Lakes. In-lake phosphorus samples should be collected from the integrated sampler early in the season (phosphorus samples collected at elbow depth will also suffice) while samples collected late in the season should be collected both in the upper waters with the technique described above and in the bottom waters using the weighted (Meyer) bottle.

Tributary sampling is also recommended and should be expanded in 1994 (i.e. Beaverdam Brook; an inlet to Duckpuddle Pond) to discern potential problem areas within the watershed. Tributary samples should be collected by submersing the phosphorus bottle into the tributary (about one foot if possible) and allowing the bottle to fill about three quarters full (allowing for expansion when frozen). The phosphorus bottle should always be pointed upstream to avoid phosphorous contamination from our bodies. When collecting phosphorus samples from a bridge the weighted bottle can be used, but be careful not to stir up the bottom sediments as this can bias the results.

3) We recommend the collection of Secchi Disk readings on intermittent weeks, when chlorophyll *a* samples are not taken, to better predict short term fluctuations which occur in

the Pemaquid Ponds. If new monitors are interested, we can set up a training session to familiarize the participants of the methodologies employed by the **NH LLMP**.

4) We recommend collecting biweekly oxygen profiles for the deeper ponds (Biscay, McCurdy and Pemaquid) to monitor the rate of oxygen depletion during summer stratification. This data will provide a more complete assessment of the trophic state of these ponds. Knowledge of the oxygen concentrations is also useful when assessing the condition of the pond's fisheries, as well as, whether or not internal nutrient cycling is contributing to the nutrient (phosphorus) pool.

5) We recommend the initiation of algal (microscopic plant) sampling to determine the phytoplanktonic community structure in the participating Pemaquid ponds. Knowledge of the algal forms will provide additional insight into the trophic state of the Pemaquid ponds. Algal samples are collected in 120 milliliter specimen jars and preserved with an iodine solution (both available through the **NH LLMP**) prior to shipping. Contact Bob Craycraft for further information.

6) Changing land use within your watershed, the surrounding land which drains into the lake, can accelerate the natural aging process. A lake typically fills in and becomes more productive on a geological time frame (thousands of years), however, this process can be accelerated to occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate the best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide applications, installing proper erosion control structures, etc.) set to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the **UNH LLMP** and the **New Hampshire Soil Conservation Service (NH SCS)**, which provides the layperson with a systematic method for recognizing and

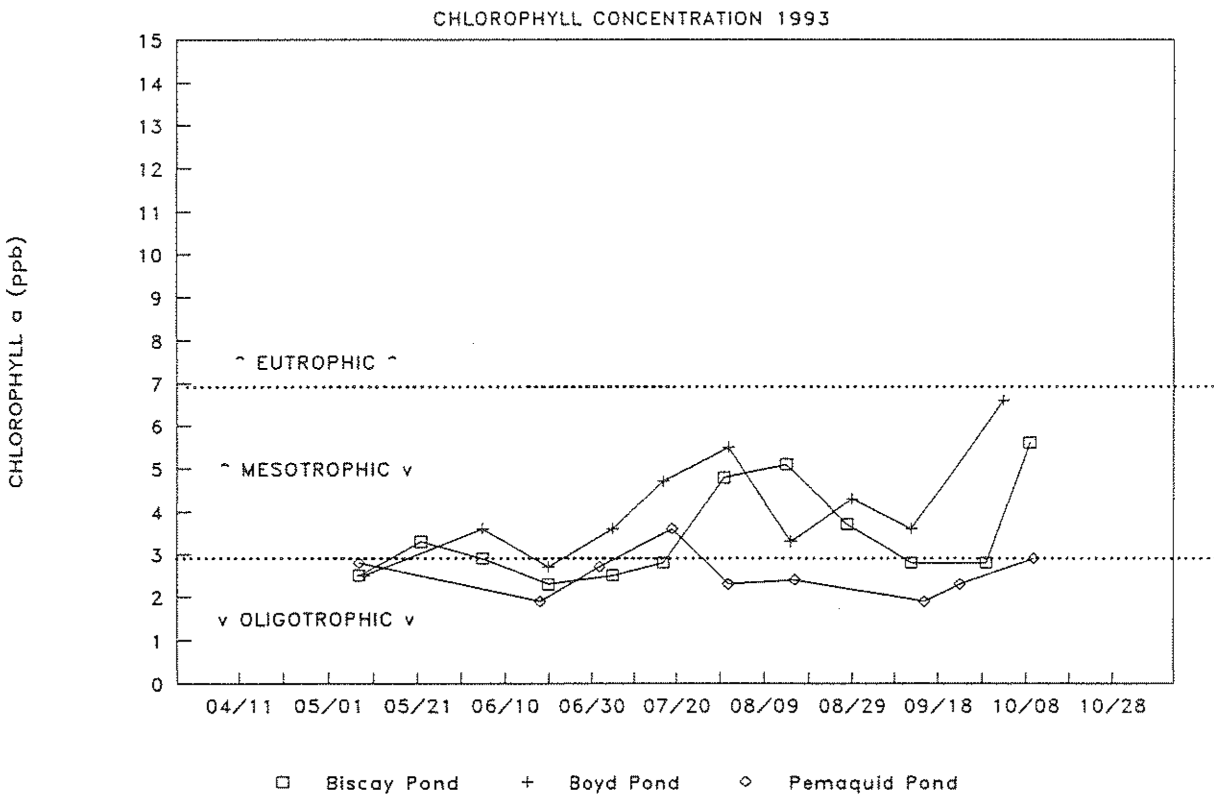
evaluating erosion, sedimentation and related non-point source (NPS) pollutant problems in New England watersheds. Contact the **LLMP** coordinator for further information.

7) We invite other interested residents to join the monitoring effort on the participating Pemaquid Lakes. The **LLMP** will provide an initial training session to review lake monitoring methodologies and help modify the monitoring program, if necessary, to meet the current concerns of the Pemaquid Watershed Association. Those interested in monitoring should contact Jeff Schloss, **LLMP** Coordinator, or Bob Craycraft, Assistant **LLMP** Coordinator.

109 Pettee Hall/UNH
Durham NH, 03824
(603) 862-3546 or 862-3848

Figure 54. Seasonal trends for chlorophyll *a* concentration in Biscay, Boyd and Pemaquid Ponds. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 55. Seasonal trends for chlorophyll *a* concentration in Duckpuddle, McCurdy and Paradise Ponds. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.


CHLOROPHYLL CONCENTRATION 1993
CHLOROPHYLL a (ppb)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
Biscay Pond
Boyd Pond
Pemaquid Pond

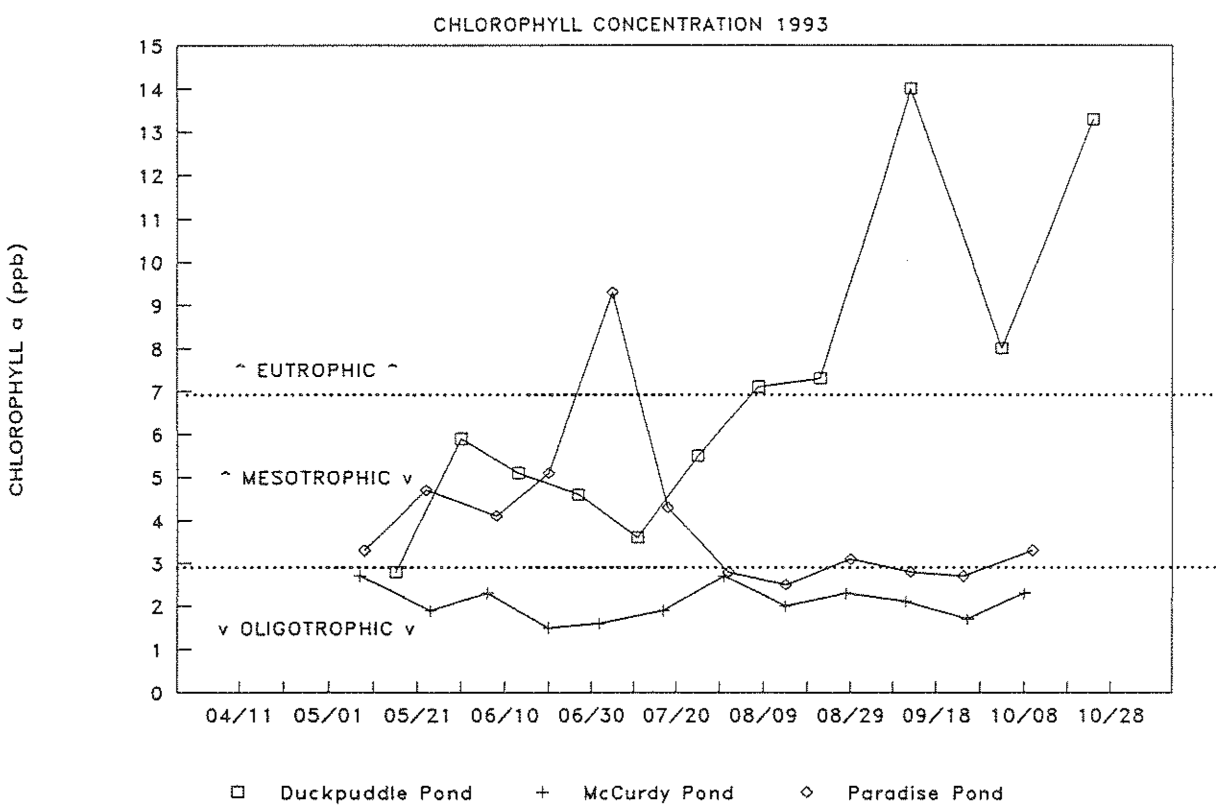
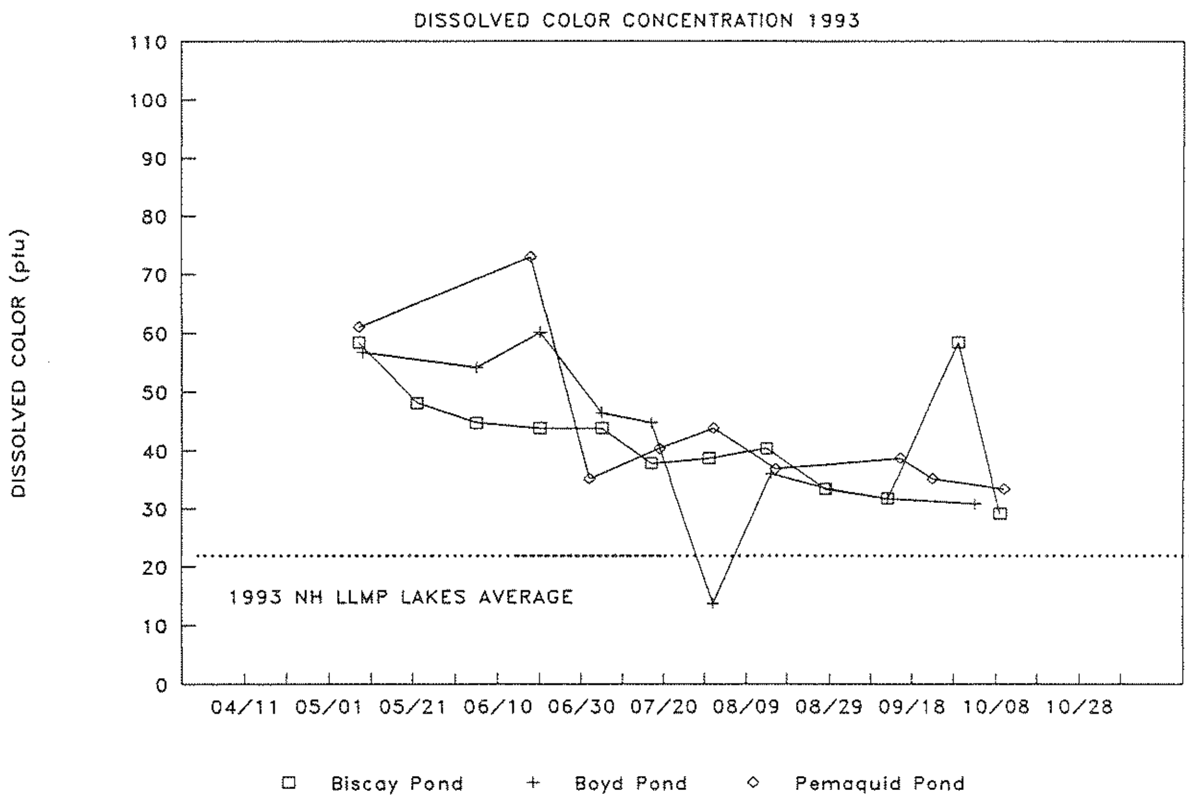

CHLOROPHYLL CONCENTRATION 1993
CHLOROPHYLL a (ppb)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
04/11
05/01
05/21
06/10
06/30
07/20
08/09
08/29
09/18
10/08
10/28
Duckpuddle Pond
McCurdy Pond
Paradise Pond

Figure 56. Seasonal trends for dissolved color concentration in Biscay, Boyd and Pemaquid Ponds. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the 1993 dissolved color average for participating **LLMP** lakes.

Figure 57. Seasonal trends for dissolved color concentration in Duckpuddle, McCurdy and Paradise Ponds. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the 1993 dissolved color average for participating **LLMP** lakes.


DISSOLVED COLOR CONCENTRATION 1993
DISSOLVED COLOR (ptu)
110
100
90
80
70
60
50
40
30
20
10
0
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
1993 NH LLMP LAKES AVERAGE
Biscay Pond
Boyd Pond
Pemaquid Pond

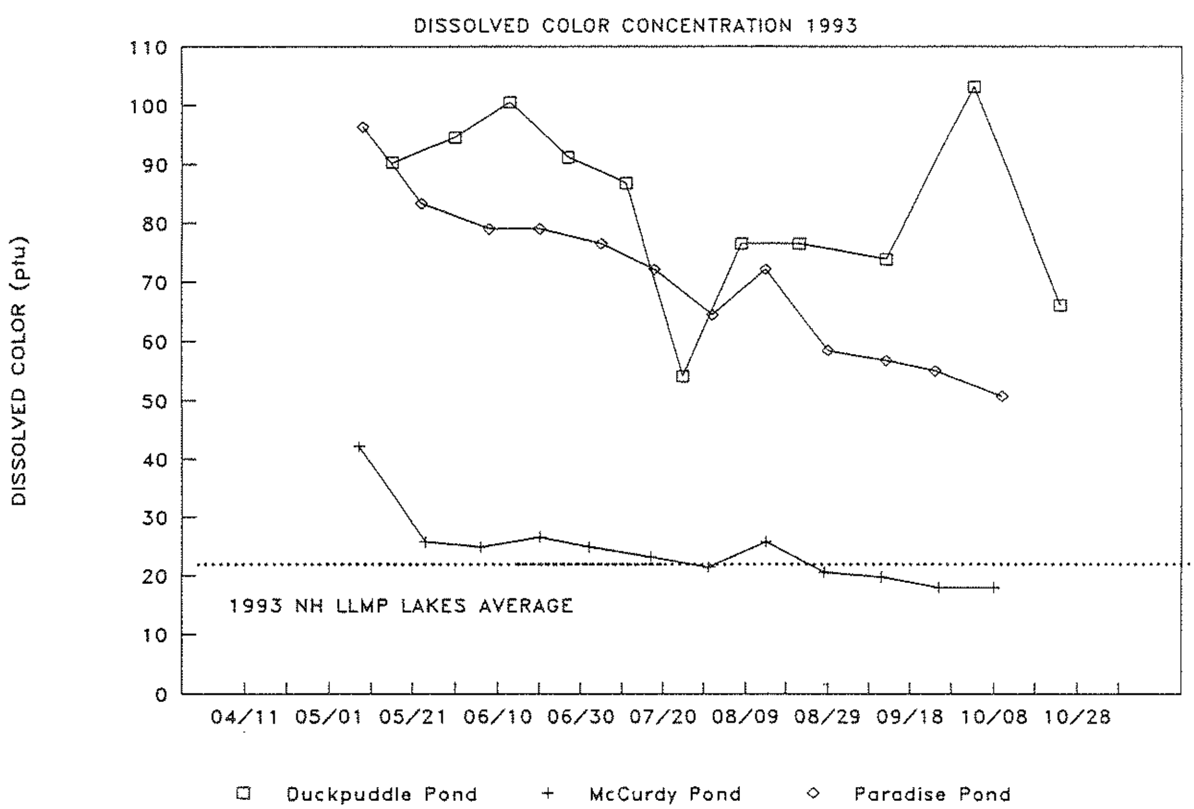

DISSOLVED COLOR CONCENTRATION 1993
DISSOLVED COLOR (ptu)
110
100
90
80
70
60
50
40
30
20
10
0
04/11 05/01 05/21 06/10 06/30 07/20 08/09 08/29 09/18 10/08 10/28
1993 NH LLMP LAKES AVERAGE
Duckpuddle Pond
McCurdy Pond
Paradise Pond

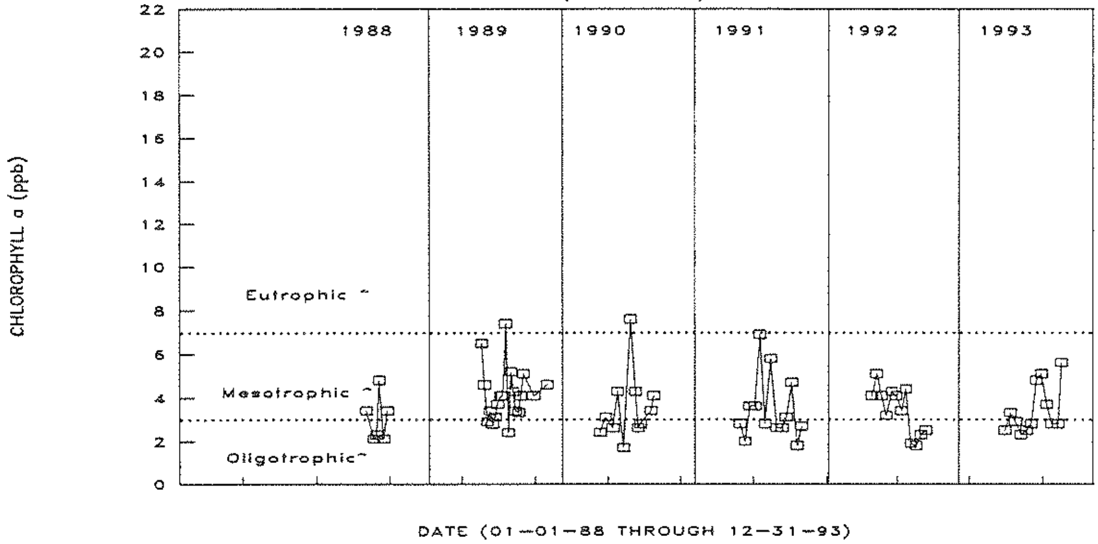
Figure 58. Seasonal Chlorophyll *a* trend analysis of Biscay Pond (1988-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 59. Seasonal Chlorophyll *a* trend analysis of Boyd Pond (1989-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 60. Seasonal Chlorophyll *a* trend analysis of Pemaquid Pond (1988-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

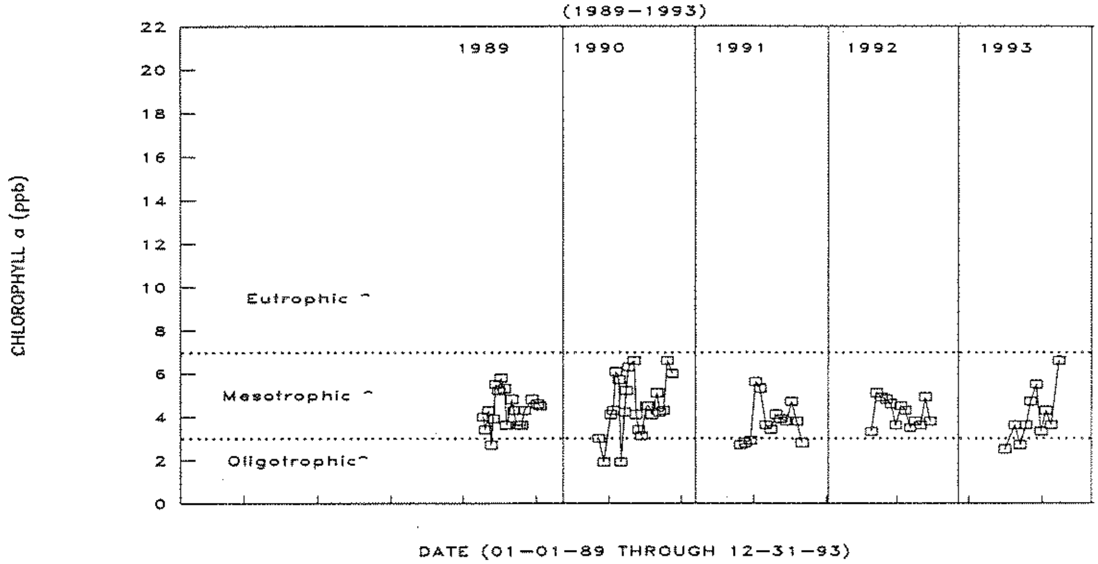
BISCAY POND — CHLOROPHYLL a TRENDS

(1988—1993)



BOYD POND — CHLOROPHYLL a TRENDS

(1989—1993)



PEMAQUID POND — CHLOROPHYLL a TRENDS

(1988—1993)

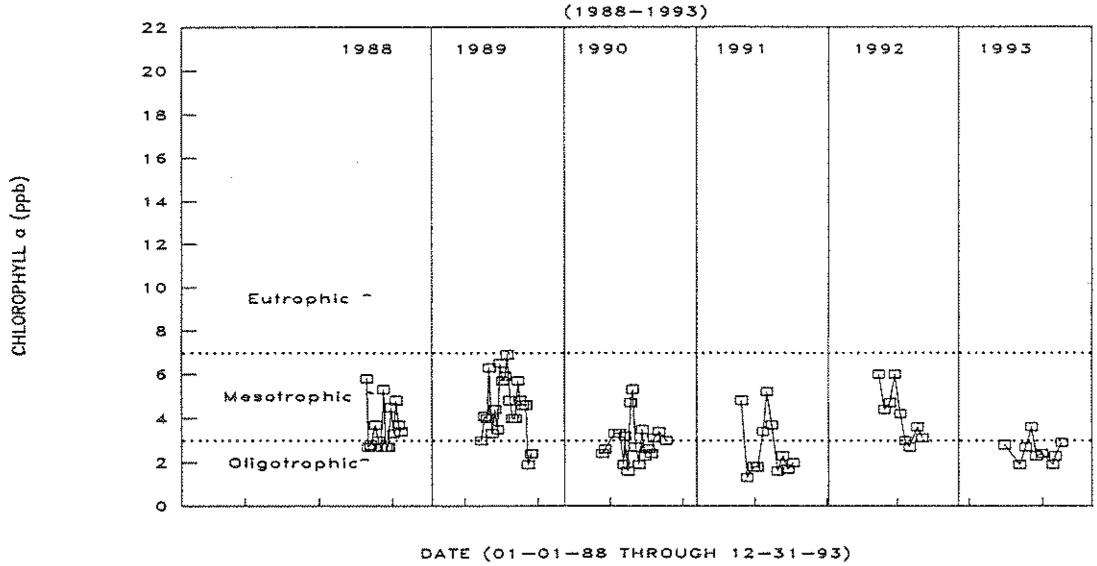
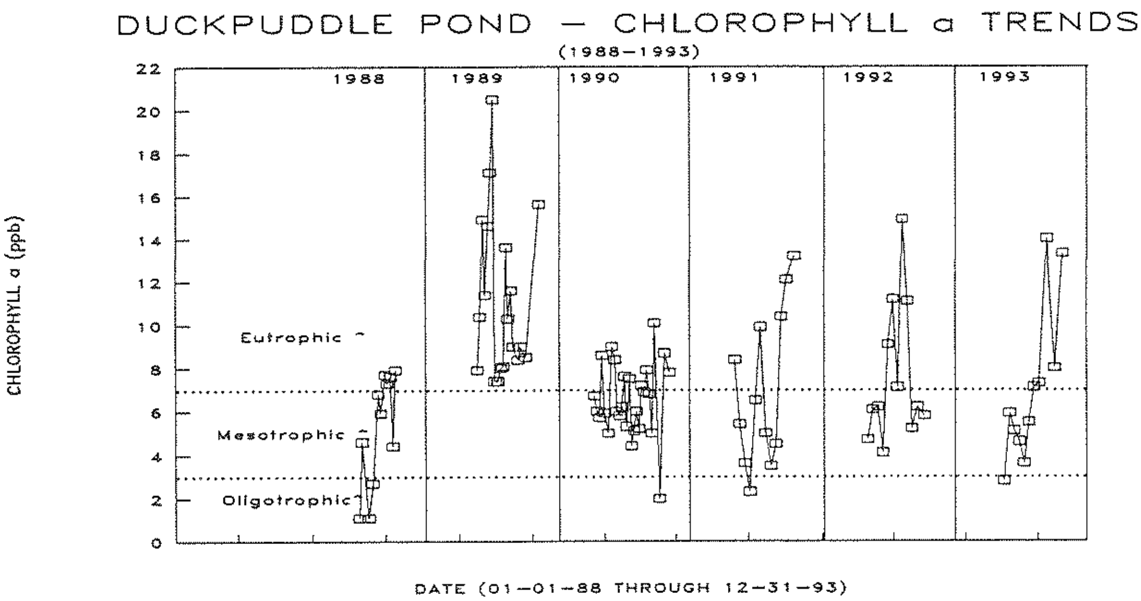
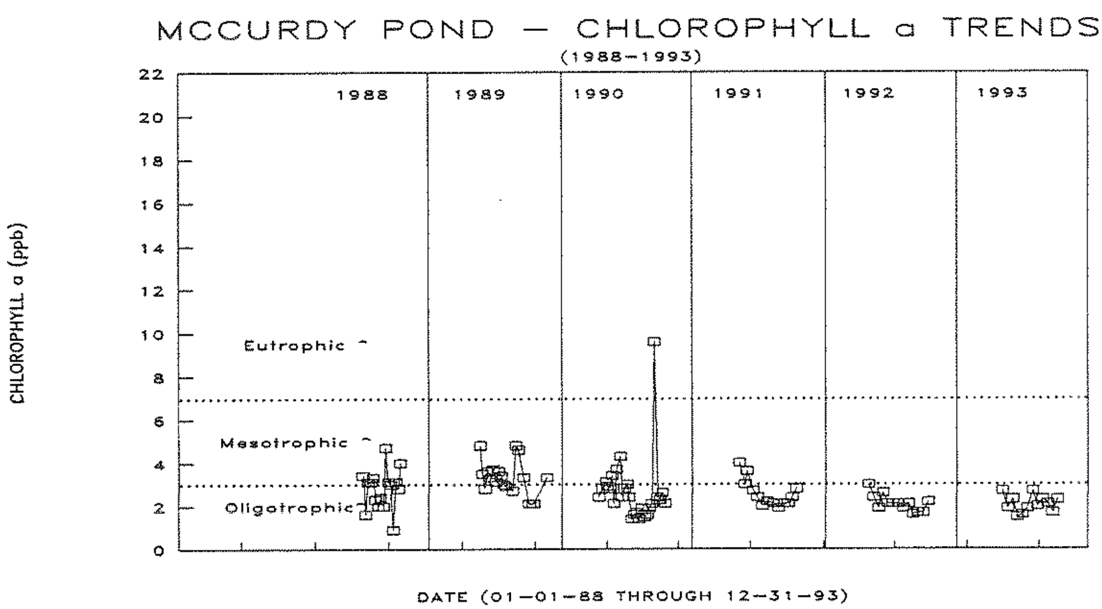


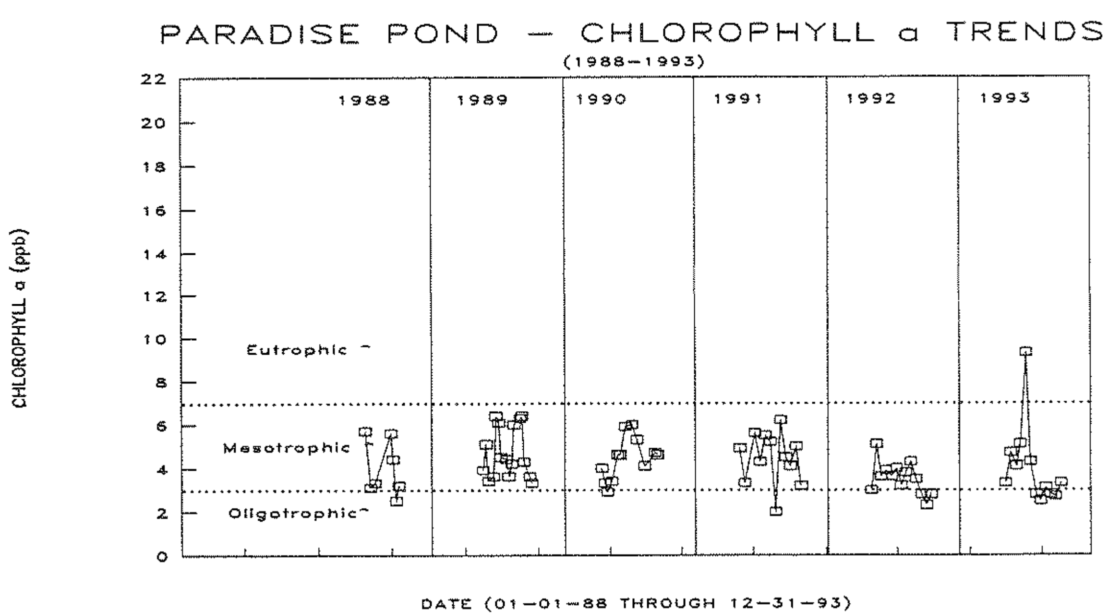
Figure 61. Seasonal Chlorophyll *a* trend analysis of Duckpuddle Pond (1988-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 62. Seasonal Chlorophyll *a* trend analysis of McCurdy Pond (1988-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.

Figure 63. Seasonal Chlorophyll *a* trend analysis of Paradise Pond (1988-1993). The dotted horizontal lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the solid vertical lines differentiate the years of sampling.


DUCKPUDDLE POND — CHLOROPHYLL a TRENDS
(1988–1993)
1988
1989
1990
1991
1992
1993
CHLOROPHYLL a (ppb)
Eutrophic
Mesotrophic
Oligotrophic
DATE (01–01–88 THROUGH 12–31–93)


MCCURDY POND — CHLOROPHYLL a TRENDS
(1988–1993)
1988
1989
1990
1991
1992
1993
CHLOROPHYLL a (ppb)
Eutrophic
Mesotrophic
Oligotrophic
DATE (01–01–88 THROUGH 12–31–93)


PARADISE POND — CHLOROPHYLL a TRENDS
(1988–1993)
1988
1989
1990
1991
1992
1993
CHLOROPHYLL a (ppb)
Eutrophic
Mesotrophic
Oligotrophic
DATE (01–01–88 THROUGH 12–31–93)

DISCUSSION OF LAKE MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1993 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire and Maine display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion**. Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion. The deeper ponds (Biscay, McCurdy and Pemaquid Ponds) became stratified into three distinct thermal layers, discussed above, while Duckpuddle and Boyd Ponds became only partially stratified, forming an epilimnetic and metalimnetic layer. No thermal stratification was noted in Paradise Pond as this pond is shallow and remains well circulated due to wind induced mixing.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Based on the classification scheme employed by the **Maine DEP**, transparency values of greater than 7 meters are typical of clear, unproductive lakes, while values of 4 meters or less are generally an indication of a productive lake. Values between 4 and 7 meters are considered typical of a moderately productive lake. In 1993 the average transparency for lakes participating in the **NH LLMP** was 5.6 meters with a range of 1.2 to 11.6 meters.

Secchi Disk readings collected at Biscay, Boyd, McCurdy and Pemaquid Ponds remained within the range common of a moderately productive lake. The water clarity of Duckpuddle Pond, on the other hand, was typical of a productive lake and decreased late in the season (September and October) when algal concentrations became elevated and thus diminished light penetration to the deeper waters. See table 7 for summary results of water clarity data from the Pemaquid Ponds.

Table 7. 1993 Secchi Disk Data and the Corresponding Maine DEP Trophic Classification.

Lake	Trans-parency (m) Minimum	Trans-parency (m) Average	Trans-parency (m) Maximum	Trophic State
Biscay Pond	4.2	5.4	6.6	Moderate
Boyd Pond	3.6	4.3	5.2	Moderate
Duckpuddle Pond	1.2	2.3	3.3	Poor
McCurdy Pond	5.0	5.7	6.5	Moderate
Paradise Pond	3.1	3.5	3.9	XXXXXXXX
Pemaquid Pond	3.5	4.7	6.0	Moderate

Chlorophyll a

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. The following classification scheme is based on the standard employed by the **Maine DEP**. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average 7 mg m^{-3} (7 milligrams per cubic meter; 7 parts per billion) or greater. **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations are generally less than or equal to 2 mg m^{-3}. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 2 mg m^{-3} and 7 mg m^{-3}. (Note: previous reports employed a classification scheme devised by Forsberg and Rydig, 1980 while the 1993 classification scheme is based on the **Maine DEP** chlorophyll *a* criteria). In 1993 the average chlorophyll for lakes participating in the **NH LLMP** was 3.0 mg m^{-3} with a range of 0.1 to 43.7 mg m^{-3}.

Surface water chlorophyll *a* levels in McCurdy Pond are typical of a borderline unproductive/moderately productive lake while those of Biscay, Boyd, Paradise and Pemaquid Ponds fall well within the criteria for a moderately productive lake (see table 8). Duckpuddle Pond continues to demonstrate the highest chlorophyll *a* concentrations which are indicative of a moderately to highly productive lake.

Table 8. 1993 Chlorophyll *a* Data and the corresponding Maine DEP Trophic Classification.

Lake	Chl *a* (ppb) Minimum	Chl *a* (ppb) Average	Chl *a* (ppb) Maximum	Trophic State
Biscay Pond	2.3	3.4	5.6	Moderate
Boyd Pond	2.5	4.0	6.6	Moderate
Duckpuddle Pond	2.8	7.0	14.0	Poor
McCurdy Pond	1.5	2.1	2.7	Moderate
Paradise Pond	2.5	4.0	9.3	Moderate
Pemaquid Pond	1.9	2.5	3.6	Moderate

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes.

Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information is important when interpreting the Secchi Disk transparency.

Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color may occur naturally but also occur during deforestation and development within the watershed. High color levels can actually mask the ability of the Secchi Disk transparency to predict chlorophyll levels.

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. See table 9 for the 1993 Pemaquid Ponds dissolved color summary statistics.

Table 9. 1993 Dissolved Color Concentrations in the Pemaquid Ponds.

Lake	Color (ptu) Minimum	Color (ptu) Average	Color (ptu) Maximum
Biscay Pond	29.2	42.4	58.4
Boyd Pond	13.7	40.8	60.1
Duckpuddle Pond	54.1	83.0	103.1
McCurdy Pond	18.0	24.3	42.1
Paradise Pond	50.7	70.3	96.2
Pemaquid Pond	33.5	44.2	73.0

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 15 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing phosphorus to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Sediment Erosion, Septic Systems, etc) will show greater concentrations of nutrients as the summer progresses or after major storm events. Circulation of nutrients from the bottom waters of more productive lakes in late fall can result in algal blooms.

The **Maine DEP** classifies lakes containing 6 ppb phosphorous or less as unproductive while those lakes containing total phosphorus concentrations of 13 ppb and greater fall into the classification of productive lakes. Lakes between 6 ppb and 13 ppb are thus classified as moderately productive lakes. Table 10 characterizes the trophic state of the Pemaquid Ponds based on the 1993 in-lake total phosphorus data and the criteria employed by the **Maine DEP**.

Table 10. 1993 In-lake Total Phosphorus Results and the corresponding Maine DEP Trophic Classification.

Lake	Date	Depth	Total Phos. (ppb)	Maine Water Quality Category
Biscay Pond	08 May 1993	Surface	7.1	Moderate
	09 Oct 1993	Surface	6.4	Moderate
Boyd Pond	09 May 1993	Surface	7.3	Moderate
	10 Oct 1993	Surface	11.5	Moderate
Duckpuddle Pond	16 May 1993	Surface	29.1	Productive
	24 Oct 1993	Surface	22.9	Productive
McCurdy Pond	08 May 1993	Surface	2.2	Good
	08 Oct 1993	Surface	8.4	Moderate
Paradise Pond	09 May 1993	Surface	8.6	Moderate
	10 Oct 1993	Surface	10.1	Moderate
Pemaquid Pond	08 May 1993	Surface	8.2	Moderate
	10 Oct 1993	Surface	12.1	Moderate

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (ie: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (grey color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 9 mg per liter (calcium carbonate alkalinity), while the average alkalinity of the lakes studied by the **Freshwater Biology Group** in the **NH LLMP** is approximately 6.3 mg per liter. When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

The classification scheme employed by the **Maine DEP** considers alkalinity levels of less than 4 ppm as low (more susceptible to acidification) while lakes with alkalinities greater than 10 ppm are considered high (more resistant to acidification).

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micro**mhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans.

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in free carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Bi-weekly oxygen profiles collected in Duckpuddle Pond revealed diminishing oxygen concentrations as the season progressed. Low oxygen concentrations in the bottom waters suggest accumulating organic matter from in both in-lake (i.e. algal and plant) as well as watershed runoff (i.e. leaf litter) sources. The reduction of oxygen concentrations below 3 ppb (the minimum requirement for most warmwater fish) suggests fish are restricted to the upper four meters of the pond during periods of prolonged thermal stratification. The reduction of oxygen, in the bottom waters, might also result in the resuspension of nutrients into the water column. While these nutrients are restricted to the anoxic waters during thermal stratification, disruption of the layering can result in the circulation of nutrients throughout the water column and thus stimulate algal growth.

<u>Underwater Light</u> *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed !). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the level where light is reduced, by the absorption and scattering properties of the lake water, to one percent of the surface intensity. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the transparency information.

Indicator Bacteria *

Coliform bacteria in water indicate the possibility of fecal contamination. Although they are usually considered harmless to humans, they are much easier to test for than harmful pathogenic enteric bacteria (**Salmonella**, **Shigella** etc.) and viruses that may be present in fecal material. **Total coliform** includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. Desirable levels for a Class A water body is less than 50 total coliform organisms per 100 milliliters. If the coliform level rises above 150 organisms per 100ml swimming should be prohibited.

Ducks and geese are often a common cause of high concentrations of coliform at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch" waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the zooplankton are discussed below in a separate section). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

Fish Condition

As with the plankton discussed above, the health of the fish species of a lake will be indicative of the overall water quality. Condition is determined by comparing the length of the fish to its weight. As would be expected, the heavier the fish for its length, the better its condition will be. By also examining a scale collected from the fish under a microscope, the approximate age and growth history can also be determined.

CURRENT CONCERN

Zebra Mussels

Since first being introduced to North America in 1986, zebra mussels (*Dreissena polymorpha*) have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least a year, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

What are Zebra Mussels?

Zebra mussels are non-native, freshwater mollusks. Their shells are marked by varying patterns of alternating dark and light bands. They are typically less than two inches long. The veligers (larval form) are free swimming, nearly invisible, and profuse. The adults secrete strong byssal threads by which they attach and reattach themselves to a variety of surfaces. These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in northwestern freshwater since the 1700s. Zebra mussels were first found in North America during 1988 in the waters of Lake Saint Clair, which is located between Lake Erie and Lake Huron. It is suspected that they arrived there as free-floating veligers (microscopic larvae) within the ballast waters of a transoceanic ship during 1986.

What do Zebra Mussels do?

In areas they infest, zebra mussels...

* attach themselves to boat hulls, creating drag and fouling moving parts.
* enter boat engine cooling systems, clogging them and causing overheating.
* colonize and clog raw water intake pipes and screens at municipal water facilities, power generating plants, industrial facilities, and shoreline residences.
* produce foul smells and bad tastes in water supplies where they are decomposing.
* litter beaches, making walking hazardous and producing unpleasant odors.

* colonize and contaminate shoals, creating inhospitable fish nesting areas and crowding them.

* compete with zooplankton (an important fish food) for phytoplankton (microscopic algae). This causes a decrease in the amount of phytoplankton and makes the water clearer. However it adversely impacts other members of aquatic food webs, including fish.

* compete with native shellfish

* become prey for diving ducks and some species of fish. However, no predator capable of controlling them has been found.

What can you do?

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

Inspect your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

Flush the cooling system, bilge areas and live wells with tap water.

Discard all bait that has contacted waters that might be infested.

Leave your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

Share information, ideas and monitoring tasks with other members of your "Lake Association", watershed council, marina club, conservation commission, angling group or civic organization.

Report any sightings to the **New Hampshire Lakes Lay Monitoring Program**. Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

Remember, so far **no** zebra mussel sightings have been substantiated in New Hampshire waterways. Confirm suspect specimens with an authority before alarming others.

How do you recognize one?

Zebra mussels commonly collect in vegetation, on docks or pilings, and along shoreline cobble and rocks.

* Adult zebra mussels are about the size of a dime and have dark and light stripes on their shells.

* Each half of the adult shell has a ridge running lengthwise down it. This creates a flat side where the two shells meet.

* Zebra mussels are the only freshwater mussels that attach to objects with byssal threads.

* A gritty feeling on your boat's hull may indicate that zebra mussel veligers have settled.

Where can you get more information?

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

Jeff Schloss
Lakes Lay Monitoring Program
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University of New Hampshire
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(603) 862-3848

or

Julia Dahlgran
Sea Grant/Cooperative Extension
Kingman Farm
University of New Hampshire
Durham, NH 03824-3512
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REFERENCES

American Public Health Association.(APHA) 1985. Standard Methods for the Examination of Water and Wastewater 16th edition. APHA, AWWA, WPCF.

Baker, A.L. 1973. Microstratification of phytoplankton in selected Minnesota lakes. Ph. D. thesis, University of Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Division of Environmental Evaluation and Lake Studies. 1991. Biscay Pond (VMP). Augusta, Maine.

Division of Environmental Evaluation and Lake Studies. 1991. Boyd Pond (VMP). Augusta, Maine.

Division of Environmental Evaluation and Lake Studies. 1991. Duckpuddle Pond (VMP). Augusta, Maine.

Division of Environmental Evaluation and Lake Studies. 1991. McCurdy Pond (VMP). Augusta, Maine.

Division of Environmental Evaluation and Lake Studies. 1991. Paradise Pond (VMP). Augusta, Maine.

Division of Environmental Evaluation and Lake Studies. 1991. Pemaquid Pond (VMP). Augusta, Maine.

Edmondson, W.T. 1937. Food conditions in some New Hampshire lakes. In: Biological survey of the Androscoggin, Saco and coastal watersheds. (Report of E.E. Hoover.) New Hampshire Fish and Game Commission. Concord, New Hampshire.

Estabrook, R.H., J.N. Connor, K.D. Warren, and M.R. Martin. 1987. New Hampshire Lakes and Ponds Inventory. Vol. III. Staff Report No. 153. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M.R. Martin and W.M. Henderson. 1988. New Hampshire Lakes and Ponds Inventory. Vol. IV. Staff Report No. 156. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M.R. Martin, P.M. McCarthy, D.J. Dubis, and W.M. Henderson. 1989. New Hampshire Lakes and Ponds Inventory. Vol. V. Staff Report No. 166. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., P.M. McCarthy, M. O'Loan, W.M. Henderson, and D.J. Dubis. 1990. New Hampshire Lakes and Ponds Inventory. Vol. VI. NHDES-WSPCD-90-3. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Estabrook, R.H., M. O'Loan and W.M. Henderson. 1991. New Hampshire Lakes and Ponds Inventory. Vol. VII. NHDES-WSPCD-91-3. New Hampshire Department of Environmental Services. Concord, New Hampshire.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-water receiving lakes. Arch. Hydrobiol. 89:189-207

Gallup, D.N. 1969. Zooplankton distributions and zooplankton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Haney, J.F. and D.J. Hall. 1973. Sugar-coated Daphnia: a preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Hoover, E.E. 1936. Preliminary biological survey of some New Hampshire lakes. Survey report no. 1. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hoover, E.E. 1937. Biological survey of the Androscoggin, Saco, and coastal watersheds. Survey report no. 2. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hoover, E.E. 1938. Biological Survey of the Merrimack watershed. Survey report no. 3. New Hampshire Fish and Game Department. Concord, New Hampshire.

Hutchinson, G.E. 1967. A treatise on limnology, Vol. 2. John Wiley and Sons, New York.

Lind, O.T. 1979. Handbook of common methods in limnology. C.V. Mosby, St. Louis.

Lorenzen, M.W. 1980. Use of chlorophyll-Secchi disk relationships. Limnol. Oceanogr. 25:371-372.

New Hampshire Water Supply and Pollution Control Commission. 1981. Classification and priority listing of New Hampshire lakes. Vol. II (Parts 1-6). Staff report no. 121. Concord, New Hampshire.

New Hampshire Water Supply and Pollution Control Commission. 1982. Classification and priority listing of New Hampshire lakes. Vol. III. Staff report no. 121. Concord, New Hampshire.

Newell, A.E. 1977. Biological survey of the lakes and ponds in Sullivan, Merrimack, Belknap and Strafford Counties. Survey report no. 8b. New Hampshire Fish and Game Department. Concord, New Hampshire.

Pearsall, Webster. Understanding Maine's Lakes and Ponds "A Guide for the Volunteer Monitoring Program". Division of Environmental Evaluation and Lake Studies. Augusta, Maine.

Schindler, D.W., et al. 1985. Long-term ecosystem stress: Effects of years of experimental acidification on a small lake. Science. 228:1395-1400.

Schloss, J.A., A.L. Baker and J.F. Haney. 1989. Over a decade of citizen volunteer monitoring in New Hampshire: The New Hampshire Lakes Lay Monitoring Program. Lake and Reservoir Management.

Sprules, W.G. 1980. Zoogeographic patterns in size structure of zooplankton communities with possible applications to lake ecosystem modeling and management. in W.C. Kerfoot ed. Evolution and Ecology of Zooplankton Communities. University Press of New England. Dartmouth. pp642-656.

Uttermohl, H. 1958. Improvements in the quantitative methods of phytoplankton study. Mitt. int. Ver. Limnol. 9:1-25.

U.S. Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

Vollenweider, R.A. 1969. A manual on methods for measuring primary productivity in aquatic environments. International Biological Programme. Blackwell Scientific Publications, Oxford.

Warfel, H.E. 1939. Biological survey of the Connecticut Watershed. Survey Report 4. N.H. Fish and Game. Concord, New Hampshire.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Philadelphia.

Wetzel, R.G. and G.E. Likens. 1979. Limnological Analyses. W.B. Saunders Co. Philadelphia.

APPENDIX A

SUMMARY STATISTICS (1988-1993)

Secchi Disk Transparency Summary Statistics (1988-1993)

Lake	Site	Year	Min Trans-parency (m)	Mean Trans-parency (m)	Max Trans-parency (m)
Biscay	1 North	1988	3.2	3.9	4.6
Biscay	1 North	1989	4.5	5.2	6.5
Biscay	1 North	1990	4.5	5.5	6.7
Biscay	1 North	1991	4.1	5.0	5.7
Biscay	1 North	1992	4.0	5.5	6.8
Biscay	1 North	1993	4.2	5.4	6.6
Biscay *	1 North	(1988-1993)	4.1	5.1	6.2
Boyd	1 Center	1989	3.3	3.8	4.5
Boyd	1 Center	1990	2.7	4.1	5.7
Boyd	1 Center	1991	3.4	3.8	4.6
Boyd	1 Center	1992	3.2	4.0	4.8
Boyd	1 Center	1993	3.6	4.3	5.2
Boyd *	1 Center	(1989-1993)	3.2	4.0	5.0
Duckpuddle	1 Basin	1988	2.0	3.0	3.7
Duckpuddle	1 Basin	1989	1.8	2.1	2.3
Duckpuddle	1 Basin	1990	1.8	2.5	3.3
Duckpuddle	1 Basin	1991	2.0	3.0	3.8
Duckpuddle	1 Basin	1992	1.8	2.9	3.5
Duckpuddle	1 Basin	1993	1.2	2.3	3.3
Duckpuddle *	1 Basin	(1988-1993)	1.8	2.6	3.3
McCurdy	1 Basin	1988	4.5	5.5	6.7
McCurdy	1 Basin	1989	4.8	5.6	7.3
McCurdy	1 Basin	1990	5.0	6.1	7.2
McCurdy	1 Basin	1991	3.3	5.4	6.3
McCurdy	1 Basin	1992	5.0	6.1	7.6
McCurdy	1 Basin	1993	5.0	5.7	6.5
McCurdy *	1 Basin	(1988-1993)	4.6	5.7	6.9
Pemaquid	1 Deep	1988	4.3	5.5	6.5
Pemaquid	1 Deep	1989	3.3	4.7	6.5
Pemaquid	1 Deep	1990	4.4	5.4	6.5
Pemaquid	1 Deep	1991	4.2	5.7	7.0
Pemaquid	1 Deep	1992	4.3	5.9	7.7
Pemaquid	1 Deep	1993	3.5	4.7	6.0
Pemaquid *	1 Deep	(1988-1993)	4.0	5.3	6.7

Note: an asterisk (*) denotes the cumulative summary statistics, for each sampling station, calculated for all years of participation in the NH LLMP.

Chlorophyll *a* Summary Statistics (1988-1993)

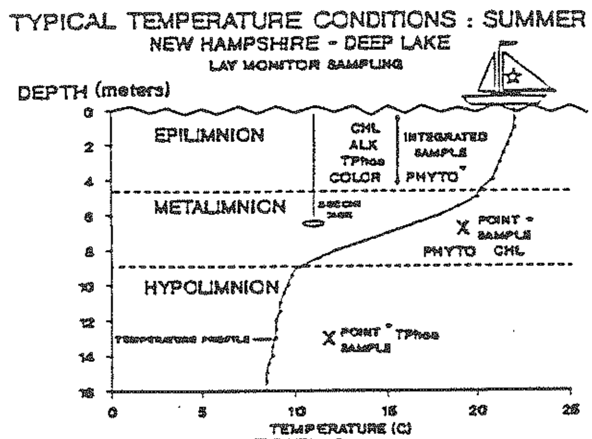
Lake	Site	Year	Min Chl *a* (ppb)	Mean Chl *a* (ppb)	Max Chl *a* (ppb)
Biscay	1 North	1988	2.1	3.0	4.8
Biscay	1 North	1989	2.4	4.2	7.4
Biscay	1 North	1990	1.7	3.5	7.6
Biscay	1 North	1991	1.8	3.5	6.9
Biscay	1 North	1992	1.8	3.4	5.1
Biscay	1 North	1993	2.3	3.4	5.6
Biscay *	1 North	(1988-1993)	2.0	3.5	6.2
Boyd	1 Center	1989	2.7	4.3	5.8
Boyd	1 Center	1990	1.9	4.5	6.6
Boyd	1 Center	1991	2.7	3.8	5.6
Boyd	1 Center	1992	3.3	4.2	5.1
Boyd	1 Center	1993	2.5	4.0	6.6
Boyd *	1 Center	(1989-1993)	2.6	4.2	5.9
Duckpuddle	1 Basin	1988	1.1	6.2	15.6
Duckpuddle	1 Basin	1989	7.4	11.1	20.5
Duckpuddle	1 Basin	1990	2.0	6.5	10.1
Duckpuddle	1 Basin	1991	2.3	7.1	13.2
Duckpuddle	1 Basin	1992	4.1	7.6	14.9
Duckpuddle	1 Basin	1993	2.8	7.0	14.0
Duckpuddle *	1 Basin	(1988-1993)	3.3	7.6	14.7
McCurdy	1 Basin	1988	0.9	2.8	4.7
McCurdy	1 Basin	1989	2.1	3.4	4.8
McCurdy	1 Basin	1990	1.4	2.7	9.6
McCurdy	1 Basin	1991	1.9	2.6	4.0
McCurdy	1 Basin	1992	1.6	2.1	3.0
McCurdy	1 Basin	1993	1.5	2.1	2.7
McCurdy *	1 Basin	(1988-1993)	1.6	2.6	4.8
Paradise	1 ReedIs	1988	2.5	4.0	5.7
Paradise	1 ReedIs	1989	3.3	4.7	6.4
Paradise	1 ReedIs	1990	2.9	4.5	6.0
Paradise *	1 ReedIs	(1988-1990)	2.9	4.4	6.0
Paradise	2 North	1991	2.0	4.5	6.2
Paradise	2 North	1992	2.3	3.5	5.1
Paradise	2 North	1993	2.5	4.0	9.3
Paradise *	2 North	(1991-1993)	2.3	4.0	6.9
Pemaquid	1 Deep	1988	2.7	3.7	5.8
Pemaquid	1 Deep	1989	1.9	4.5	6.9
Pemaquid	1 Deep	1990	1.6	3.0	5.3
Pemaquid	1 Deep	1991	1.3	2.7	5.2
Pemaquid	1 Deep	1992	2.7	4.2	6.0
Pemaquid	1 Deep	1993	1.9	2.5	3.6
Pemaquid *	1 Deep	(1988-1993)	2.0	3.4	5.5

Note: an asterisk (*) denotes the cumulative summary statistics, for each sampling station, calculated for all years of participation in the **NH LLMP**.

Dissolved Color Summary Statistics (1988-1993)

Lake	Site	Year	Min Color (ppb)	Mean Color (ppb)	Max Color (ppb)
Biscay	1 North	1989	30.1	44.0	56.7
Biscay	1 North	1990	37.8	43.0	49.0
Biscay	1 North	1991	37.8	52.7	63.6
Biscay	1 North	1992	31.8	43.7	57.6
Biscay	1 North	1993	29.2	42.4	58.4
Biscay *	1 North	(1989-1993)	33.3	45.2	57.1
Boyd	1 Center	1989	36.1	51.4	65.3
Boyd	1 Center	1990	36.1	55.0	120.3
Boyd	1 Center	1991	43.0	60.9	84.2
Boyd	1 Center	1992	32.6	43.5	55.8
Boyd	1 Center	1993	13.7	40.8	60.1
Boyd *	1 Center	(1989-1993)	32.3	50.3	77.1
Duckpuddle	1 Basin	1988	67.9	76.0	86.8
Duckpuddle	1 Basin	1989	78.2	103.6	125.4
Duckpuddle	1 Basin	1990	68.7	96.0	116.8
Duckpuddle	1 Basin	1991	73.9	92.4	113.4
Duckpuddle	1 Basin	1992	66.1	79.6	103.9
Duckpuddle	1 Basin	1993	54.1	83.0	103.1
Duckpuddle *	1 Basin	(1988-1993)	68.2	88.4	108.2
McCurdy	1 Basin	1988	11.2	21.2	44.7
McCurdy	1 Basin	1989	11.2	24.5	30.1
McCurdy	1 Basin	1990	14.6	25.5	74.7
McCurdy	1 Basin	1991	16.3	32.2	53.3
McCurdy	1 Basin	1992	12.9	21.6	34.4
McCurdy	1 Basin	1993	18.0	24.3	42.1
McCurdy *	1 Basin	(1988-1993)	14.0	24.9	46.6
Paradise	1 ReedIs	1988	61.8	68.4	79.9
Paradise	1 ReedIs	1989	54.1	76.9	94.5
Paradise	1 ReedIs	1990	57.6	75.7	89.3
Paradise *	1 ReedIs	(1988-1990)	57.8	73.7	87.9
Paradise	2 North	1991	55.8	75.3	92.8
Paradise	2 North	1992	55.0	71.0	87.6
Paradise	2 North	1993	50.7	70.3	96.2
Paradise *	2 North	(1991-1993)	53.8	72.2	92.2
Pemaquid	1 Deep	1988	25.8	36.3	50.7
Pemaquid	1 Deep	1989	30.1	52.6	68.7
Pemaquid	1 Deep	1990	36.1	49.6	66.1
Pemaquid	1 Deep	1991	36.9	57.6	113.4
Pemaquid	1 Deep	1992	22.3	43.2	58.4
Pemaquid	1 Deep	1993	33.5	44.2	73.0
Pemaquid *	1 Deep	(1988-1993)	30.8	47.3	71.7

Note: an asterisk (*) denotes the cumulative summary statistics, for each sampling station, calculated for all years of participation in the **NH LLMP**.



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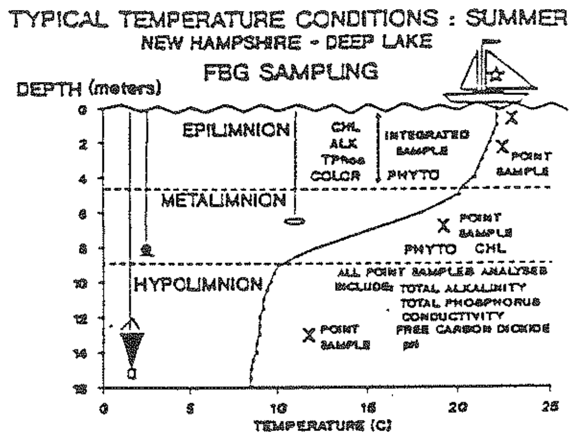

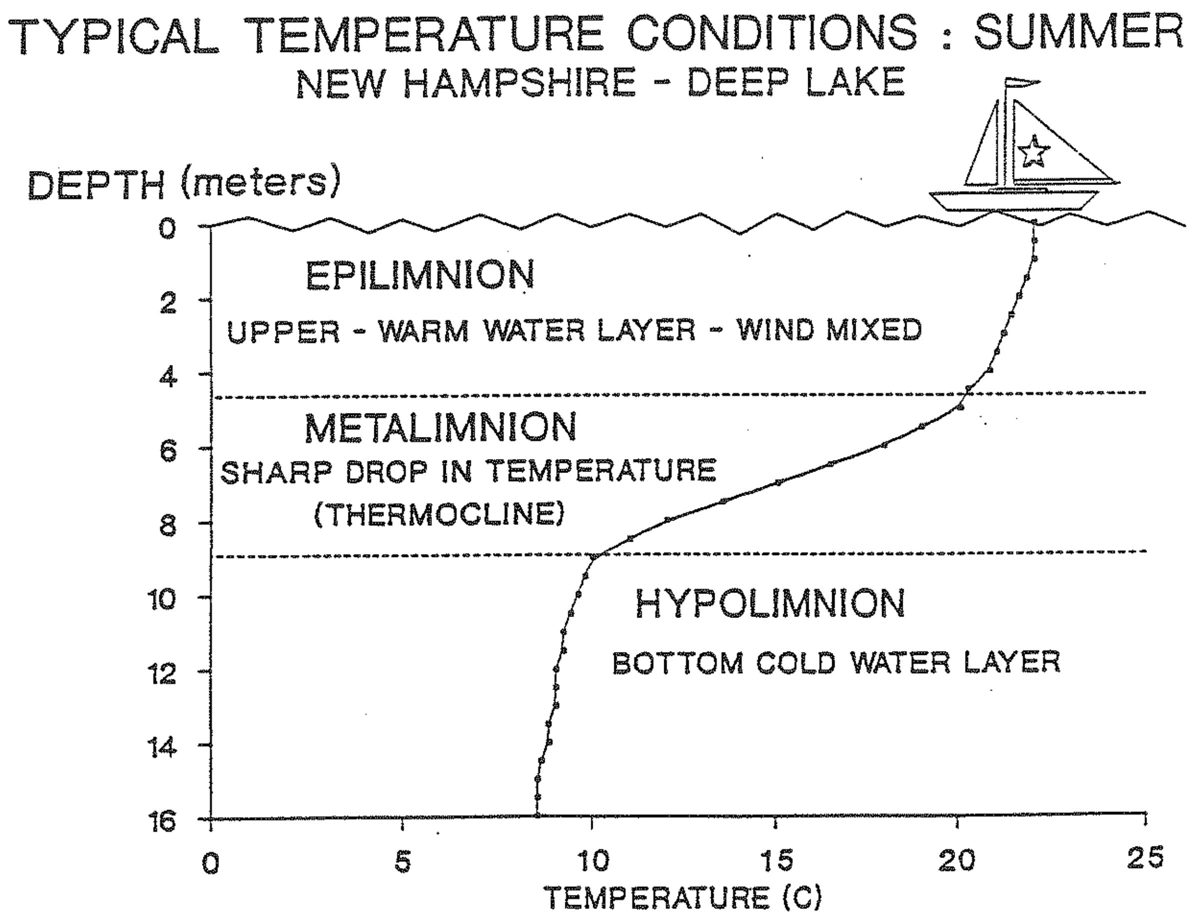

APPENDIX C

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids-Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion-The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion-The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion- Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton-Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.